Environmental Security Technology Certification Program
(ESTCP)

RESULTS AND LESSONS LEARNED INTERIM REPORT: ALTUS AFB SITE

July 7, 2005

Issued by Groundwater Services, Inc.
Houston, Texas
Job No. G-2882

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **7 JUL 2005**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE
Results and Lessons Learned Interim Report: Altus AFB Site

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER
ER-0423

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Groundwater Services, Inc. 2211 Norfolk, Suite 1000 Houston, TX 77098-4044 Houston, Texas

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Environmental Security Technology Certification Program 901 N Stuart Street, Suite 303 Arlington, VA 22203

10. SPONSOR/MONITOR’S ACRONYM(S)
ESTCP

11. SPONSOR/MONITOR’S REPORT NUMBER(S)
ER-0423-IR

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT
Intensely monitored sites, such as the Borden Landfill in Canada, have greatly contributed to our understanding of the physical and chemical processes that control the transport of chemicals in groundwater. For this project, we have used a similar approach (i.e., intensively monitored sites with specially-designed monitoring networks) to address the critical groundwater-to-indoor-air vapor intrusion pathway. By increasing our understanding of this critical pathway, guidelines can be improved, thereby better focusing Department of Defense (DoD) efforts and associated cost increases on only those sites where indoor vapor concerns are warranted. This interim report presents our results for the evaluation of vapor intrusion processes at the first of three demonstration sites: the Building 418 at the Altus Air Force Base (AFB), Oklahoma.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**110**	

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RESULTS AND LESSONS LEARNED INTERIM REPORT: ALTUS AFB SITE

1.0 Introduction and Background

1.1 Project Overview

Intensely monitored sites, such as the Borden Landfill in Canada, have greatly contributed to our understanding of the physical and chemical processes that control the transport of chemicals in groundwater. For this project, we have used a similar approach (i.e., intensively monitored sites with specially-designed monitoring networks) to address the critical groundwater-to-indoor-air vapor intrusion pathway. By increasing our understanding of this critical pathway, guidelines can be improved, thereby better focusing Department of Defense (DoD) efforts and associated cost increases on only those sites where indoor vapor concerns are warranted. This interim report presents our results for the evaluation of vapor intrusion processes at the first of three demonstration sites: the Building 418 at the Altus Air Force Base (AFB), Oklahoma.

1.2 Study Objectives

The primary objective of this demonstration study is to identify and validate the limited site investigation scope that provides the most accurate and reliable evaluation of vapor intrusion at corrective action sites. At the three demonstration sites, this objective will be met by:

1) Collecting a high density of data related to vapor intrusion at the test site,
2) Analyzing this data to obtain a thorough understanding of vapor intrusion processes at the test site, and
3) Evaluating subsets of the data which reflect various options for conducting a limited scope vapor intrusion investigation in order to determine which subset provides the most accurate indication of the actual vapor intrusion at the site.

In order to support this objective, the following specific data evaluation objectives have been established:

1) <u>Characterize the Distribution of VOCs Within Environmental Media</u>: Characterize the spatial variability in volatile organic compound (VOC) distribution within specific environmental media. Describe the differences in variability between media. Sample on multiple dates to define both short-term variability in VOC distribution and longer-term seasonal variability in VOC mass distribution.

2) <u>Measure VOC Transfer at Saturated/Unsaturated Zone Interface and throughout Vapor Migration Pathway</u>: Obtain detailed information regarding the mass flux of VOCs: i) with depth within the groundwater-bearing unit, ii) in the soil capillary zone fluids above

the water table, iii) vertically within the unsaturated soil column, and iv) through the building foundation.

3) Characterize Measurable Site Parameters Related to Vapor Migration Potential: Sample and analyze soils in saturated and unsaturated soil zones and evaluate building characteristics to understand physical parameters that may control potential for and rate of vapor migration, including: soil lithology, depth to groundwater, height of capillary fringe, soil hydraulic conductivity and air permeability, soil water retention characteristics, vertical distribution of volumetric moisture content in unsaturated zone, soil organic carbon content, groundwater flow gradient, indoor air exchange rate, building differential pressure, etc.

4) Characterize Vapor Intrusion Mechanisms and Drivers: Conduct detailed analysis of site database to characterize groundwater to vapor transport mechanisms (diffusion in groundwater, groundwater to vapor transfer, vapor diffusion, vapor-structure interaction, VOC mass balance, temporal variation, etc.) and the importance of key site parameters (groundwater concentration, groundwater mass flux, capillary height, soil moisture profile, soil permeability, etc.) to vapor mass flux into the structure.

This interim report presents the methods and results for the first of three demonstration sites, Building 418 at Altus AFB. In addition, this report provides an evaluation of the data with respect to the project objectives and provides preliminary conclusions and recommendations for demonstration plan modifications based on lessons learned.

1.3 Overview of the Altus AFB Study Site

The first of three field vapor intrusion investigation demonstrations was conducted in and around Building 418 on the Altus AFB, located near the southern boundary of the facility. A map of the facility, including the location of Building 418, is presented as Figure 1. The groundwater plume underlying the test building has been extensively characterized as part of the RCRA Facility Investigation (RFI) process underway at Altus AFB.

The test building is a single-story slab-on-grade office building approximately 150 ft long by 50 ft wide (see Figure 2). The building is used primarily for classroom instruction. Based on the small size and non-industrial use, the building is representative of large houses, small apartment buildings, and small office buildings. The test building is underlain by a shallow dissolved chlorinated solvent groundwater plume containing elevated concentrations of tetrachloroethene (PCE), trichloroethene (TCE), and cis-1,2-dichloroethene (cis-1,2-DCE). This plume has been designated as the SS-17 plume as part of the RFI process (Earth Tech, 2002).

The local subsurface geology consists of clay, sandy clay, residual soils resulting from the weathering of shale, and alluvium resulting from the erosion and deposition of the surface materials (which includes fill associated with construction activities). The fill, clay, disturbed residual soils, and alluvium are difficult to separate and are collectively referred to as the sediment/overburden. This sediment/overburden appears to cover the entire site. The transition from sediment/overburden to the more competent shale is not a readily defined horizon, however, the sediment/overburden is generally considered to extend 12 to 20 ft below ground surface (bgs) in the vicinity of Building 418. In general, the extent of weathering within the shale becomes less with depth. Both the vertical and horizontal migration of chlorinated VOCs at SS-17 have been influenced by the permeability of the subsurface materials that can be enhanced by the weathering process. Geologic cross-sections extending from the north-west to the south-east and from the west to the east are presented in Attachment A, Figures 4.5.1-2, 4.5.1-3, and 4.5.1-5.

The potentiometric surface within the sediment/overburden is located 3 to 10 ft bgs and varies seasonally by up to 4 ft. An evaluation of the potentiometric surface reveals a range of hydraulic gradients from 0.0006 ft/ft to 0.008 ft/ft with groundwater flow to the southeast. Within the immediate vicinity of Building 418, the hydraulic gradient is 0.0066 ft/ft and is generally to the south – southeast (Earth Tech, 2002).

Within the area of the SS-17 groundwater plume, the hydraulic conductivity values range from 7×10^{-4} cm/sec to 9×10^{-3} cm/sec. Based on slug test results from monitoring wells WL139 and WL315, the hydraulic conductivity in the vicinity of Building 418 is approximately 4.1×10^{-3} cm/sec. Based on calculations using the observed gradient and hydraulic conductivity in the vicinity of Building 418, the groundwater Darcy velocity is approximately 7.6×10^{-2} ft/day. A potentiometric surface map of the shallow water-bearing-unit underlying the test area is provided as Figure 4.5-2 in Attachment A.

The SS-17 plume has been characterized through the installation and sampling of over 230 monitoring wells including 135 shallow wells, 81 medium depth wells, and 14 deep wells. The shallow wells generally have 10 ft screens with top-of-screen depths ranging from 3 to 7 ft bgs. The medium depth wells typically have 10 ft screens with top-of-screen depths of 28 to 32 ft bgs.

This network of wells has served to delineate a TCE plume approximately 4000 ft long and 1200 ft wide originating from two buildings located 500 and 800 ft north of the test building, resulting in TCE concentrations of approximately 200 ug/L in groundwater below the test building, based on 2000 and 2001 analytical results (Earth Tech, 2002). Smaller plumes of PCE and 1,2-DCE appear to originate in the same areas and also extend under the test building. Isoconcentration maps of TCE, PCE and DCE plumes are provided in Attachment A as Figures 4.5.1-17, 4.5.1-22, and 4.5.1-20, respectively.

In order to provide an overview of key site information, the following figures have been included as Attachment A.

- Figure 4.5.1-2 SS-17 Cross-Section Location Map
- Figure 4.5.1-3 SS-17 Geologic Cross-Section 5A-5A'
- Figure 4.5.1-5 SS-17 Geologic Cross-Section 5C-5C'
- Figure 4.5.1-17 SS-17 Groundwater TCE Isoconcentration Map Upper Wells, 2001
- Figure 4.5.1-22 SS-17 Groundwater PCE Isoconcentration Map Upper Wells
- Figure 4.5.1-20 SS-17 Groundwater DCE Isoconcentration Map Upper Wells
- Figure 4.5-2 Group 5 Potentiometric Surface Map, Upper Wells, May 2001

1.4 Overview of Testing Program

In order to characterize the distribution of site VOCs across environmental media at the test building, a comprehensive field vapor intrusion investigation program has been conducted. This investigation program included the following components:

1) Sample Point Installation: Installation of permanent sampling points and collection of geotechnical samples.

2) Purge Study: Completion of a purge study to determine the optimal purge volume for each type of sampling point in order to obtain results representative of the environmental medium and sampling location.

3) Sample Event 1: Collection of samples from all sample points and analysis for site chemicals of concern (COCs).

4) Sample Event 2: On a separate day, collection of another set of samples from all sample points and analysis for site COCs.

5) Fixed Gases: Collection of samples from subsurface sampling points and measurement of oxygen and carbon dioxide concentrations.

6) Tracer Gas Study: Release of tracer gas (SF6) inside building and collection of samples to determine the building air exchange rate.

7) Radon Study: Collection of sub-slab and indoor samples and analysis for radon to measure the slab attenuation factor.

8) Cross-Foundation Pressure Gradient: Measurement of the pressure gradient across the building foundation in order to determine the pressure forces influencing advection through the building slab.

Sampling methods, results, data evaluation, and conclusions are provided in Section 2 through 5 of this report.

2.0 Sampling and Analysis Methods

2.1 Installation of Subsurface Sampling Points

A total of 27 subsurface sampling points were installed at the demonstration site during the two-week field program.

2.1.1 Groundwater Monitoring Well Points

Monitoring wells for groundwater and well headspace sampling were installed using traditional direct push techniques. Three monitoring well clusters were installed with each cluster consisting of four wells with vertically spaced screens (see Figures 2 and 3). Borings were advanced with a track-mounted Geoprobe unit to depths specified by the demonstration plan. Based on the expected static water level of approximately 4 ft bgs, the four monitoring wells in each cluster were installed with well screens of 3.5 to 4.5 ft bgs, 5.5 to 6.5 ft bgs, 7.5 to 8.5 ft bgs, and 9.5 to 10.5 ft bgs, respectively. The deepest boring (10.5 ft) was advanced first and was used to log the shallow geology. The next deepest boring was advanced to 8.5 ft bgs and was used to collect 3 representative samples for geotechnical analysis. The remaining two borings were advanced to 6.5 and 4.5 ft bgs with no sample collection or logging.

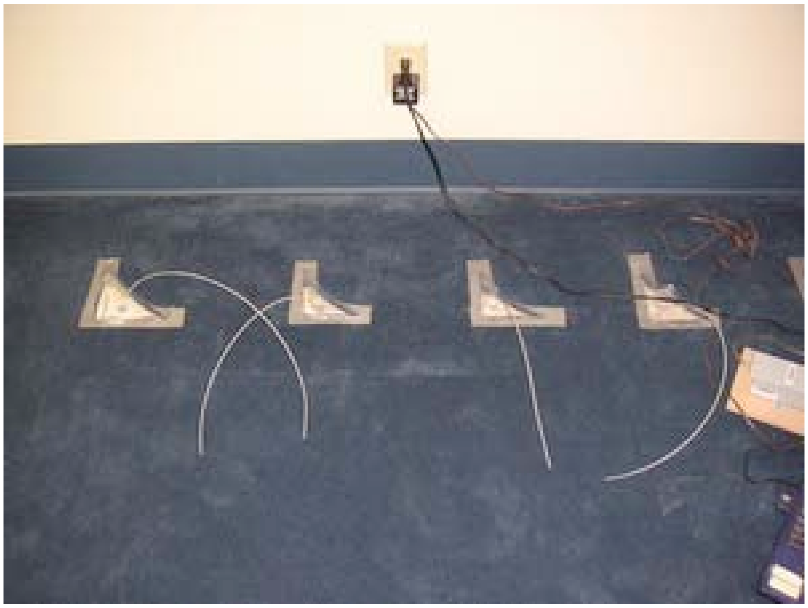
Monitoring wells were constructed of one inch schedule 40 PVC pipe with flush threaded joints. The well screen consists of one foot of number ten slotted PVC with a threaded cap on the bottom with no sump. The screened interval of the well was pre-packed with U.S. mesh interval 20/40 sand. The remainder of the borehole was filled with bentonite chips and hydrated to create an annular seal. Monitoring wells were capped with a tight fitting PVC slip cap. Monitoring wells were completed at the surface using an aluminum flush mount man-way installed in a 4 ft x 4 ft concrete pad. For the midgradient and downgradient clusters, a single concrete pad was installed at each location and encompassed all 4 monitoring well man-ways and all 4 soil gas sampling points. The upgradient cluster was in an asphalt parking lot and each man-way was completed individually at this location (i.e., no concrete pad). Example construction specifications are shown on Figure 4.

Soil Gas and Monitoring Well Cluster Prior to Pad Completion.
Note: Larger 1” diameter casings are the monitoring wells, smaller 1/2” casings are the soil gas points.

2.1.2 Soil Gas Points

Two vertical clusters of soil gas points were installed outside, adjacent to Building 418 and one vertical cluster was installed through the building foundation (see Figure 2). The soil gas points installed outside were installed in the same manner as the monitoring wells using direct push techniques to depths of 1, 2, 3, and 4 ft bgs based on the apparent static water level in the area of 4 ft bgs. Soil gas points were installed outdoors at the upgradient and downgradient cluster locations. The outdoor soil gas points were constructed of 1/2 inch diameter schedule 40 PVC pipe with flush threaded joints. The sample screen consists of two inches of number ten slotted PVC with a threaded cap on the bottom. A sand pack using U.S. mesh interval 20/40 sand was installed around the screen and extended several inches above the screened interval. The remainder of the borehole was filled with bentonite chips and hydrated to create an annular seal. Soil gas sampling points were capped with a tight fitting PVC slip cap. Outdoor soil gas points were completed using an aluminum flush mount man-way installed in the existing asphalt parking lot or a 4 ft x 4 ft concrete pad, as described for the monitoring wells. Example construction specifications are shown on Figure 4.

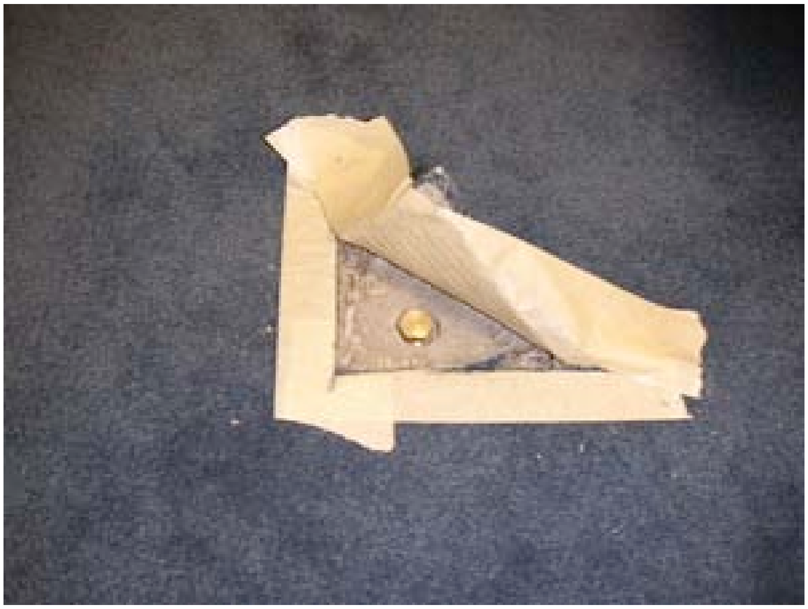
Indoor soil gas points were installed for the midgradient cluster to depths of 1, 2, 3, 4, and 5.5 ft bgs. Boreholes for the indoor soil gas points were advanced using a 3/4 inch steel rod driven to the correct depth through a one inch hole bored in the building’s concrete slab. The sample points consisted of an aluminum point with a hollow screened area with a connection for attachment of sampling tubing. This sample point was attached securely to 1/8th inch Nylaflow tubing and lowered to the bottom of the boring. Coarse sand was installed around the point and up to several inches above the point. The borehole was sealed from atmospheric air by one to two feet of cement pumped into the borehole immediately above the sand pack. Example construction specifications are shown on Figure 4.



Indoor Soil Gas Points.

2.1.3 Sub-Slab Sample Points

Sample points for the collection of sub-slab gasses were installed by drilling a 1/2 inch hole through the building slab and into the underlying soil or fill material to a depth of 3 to 4 inches below the base of the foundation. A 3/16th inch stainless steel tube attached to a female 1/4 inch compression fitting was installed in the hole to a depth roughly equivalent with the bottom of the slab. An annular seal was created by placing cement around the stainless steel tube and the compression fitting. The sample point was completed by the installation of a threaded plug that was flush with the foundation after installation. The 1/4 inch threaded compression fitting allowed for the attachment of a sample train for sample collection. Example construction specifications are shown on Figure 4.



Sub-Slab Sample Port.
Note: Picture shows port capped with flush threaded plug.

2.2 Collection of Geotechnical Samples

Geotechnical samples were collected during monitoring well installation at the 3 outdoor sample point clusters (see Figure 6) from the 8.5 ft soil borings. A total of 9 1-ft soil core samples were collected (3 depth intervals from 3 locations). At each location, the three samples were vertically spaced to cover the variation in lithology observed in the 10.5 ft boring previously collected from that location. Samples were collected by retaining the soils in the plastic sleeve used in boring advancement, cutting out the desired depth interval, and then capping the ends with duct tape to ensure an air-tight seal. The samples were kept on wet ice until delivery to PTS Laboratories in Houston, Texas.

2.3 Collection of Samples for Chemical Analysis

During the second week of the field program, samples were collected for chemicals analysis. The sample collection methods are described below.

2.3.1 Groundwater Sample Collection

Prior to sampling, all groundwater sampling points were gauged to determine whether groundwater had infiltrated the well and to measure the static water level. Monitoring wells installed for the demonstration project were pumped dry using a low-flow peristaltic pump with disposable dedicated tubing and allowed to recharge prior to the sampling event. Following recharge, groundwater was collected using the peristaltic pump and placed in method-specific containers, 40 mL VOA vials. During the first sampling event, physical properties such as temperature, specific conductance, and pH were measured if there was sufficient sample volume.

Existing groundwater wells (all with 10 ft screened intervals) were sampled using a low-flow sampling technique. A peristaltic pump was used to pump water at a rate that did not significantly influence the static water level in the well, usually around 50 to 75 milliliters per minute. The physical groundwater parameters temperature, specific conductance, and pH were checked every few minutes while pumping until the readings stabilized, after which time samples were collected. Samples were collected in method-specific containers and immediately placed on ice. Water generated from development and sampling activities was contained in a bucket for transport and final disposition.

2.3.2 Gas Sample Collection

Gas samples collected for analysis by the on-site mobile laboratory were collected using 50 mL gas-tight syringes. The syringes were equipped with a 3-way valve that allowed for sealing the syringe following sample collection. Filled syringes were immediately delivered to the on-site mobile lab for analysis within one hour of sample collection. The syringe and 3-way valve sampling system used for sample collection is shown on Figure 5.

Gas samples collected for analysis off-site by method TO-15 were collected using 400 mL mini Summa canisters. Summa canisters were provided under vacuum and samples were collected by attaching the summa canister to the sample train and allowing the sample to be drawn in by the vacuum. A vacuum gauge incorporated in the summa canister sample train was used to monitor the vacuum and ensure sample collection. The summa canister sampling system is shown on Figure 5.

Sample Collection: Soil Gas Sample.

2.3.3 Well Headspace Sample Collection

Two methods were used for the collection of gas samples from the headspace of monitoring wells. The first method (Nylaflow) used 1/8th inch Nylaflow tubing placed inside the well casing to the desired sample point. For this method, the top of the monitoring well was left open to the atmosphere during sample collection. The very small diameter of the sample line resulted in very low purge volumes and minimal disturbance of the subsurface gasses being collected. The second method (1/4 Inch Tubing) used 1/4 inch tubing connected to the inside of the PVC slip cap placed on the well casing with the tubing extending to the desired sample depth. This system allowed the monitoring well to be sealed from the atmosphere during sample collection. The larger diameter tubing resulted in larger purge volumes and greater disturbance of the subsurface gasses. These two sample collection methods are depicted on Figure 5. A comparison of analytical results obtained using the two sample collection methods is provided in Section 4.2 of this report.

2.3.4 Soil Gas Sample Collection

Soil gas samples were collected from the outdoor 1/2 inch soil gas sample points using the two methods described above for the collection of well headspace samples (i,e, Nylaflow and 1/4 inch tubing) plus a third method, whole casing purge. For the whole casing purge method, the sample train was attached to the slip cap cover for the sample point, with no tubing inside the sample point (see Figure 5). As a result, the sample point was sealed from the atmosphere during sample collection, but the purge volume included the entire volume of the sample point PVC casing (i.e., 60 mL per ft). A comparison of analytical results obtained using the three sample collection methods is provided in Section 4.2 of this report.

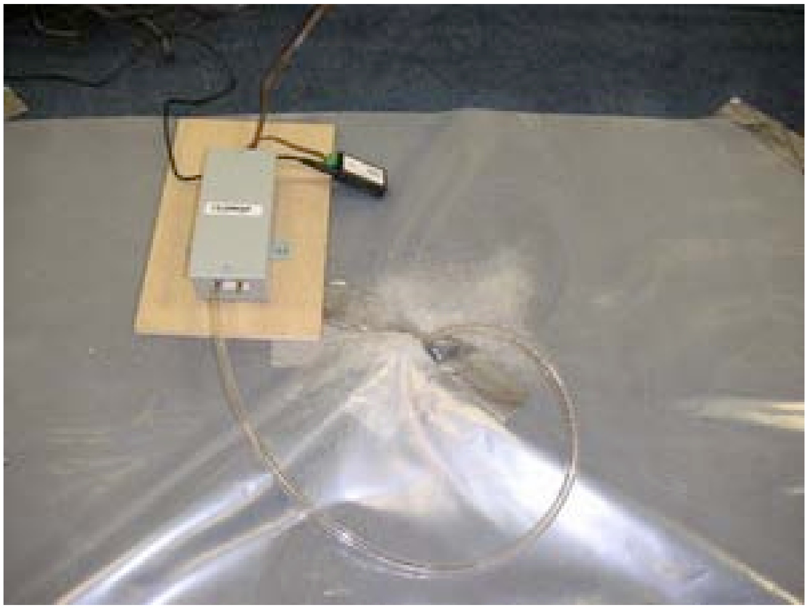
Soil gas samples were collected from the indoor soil gas sample points by attaching the sampling train to the 1/8th inch Nylaflow tubing extending from the subsurface sample point (see Figure 4). Sub-slab gas samples were collected by attaching the sample train to the top of the sample port (see Figure 5). The sample line volume of the sub-slab sample point was estimated to be 10 mL total.

2.3.5 Sample Collection for Radon Analysis

Samples for the analysis of radon were collected from indoor and sub-slab sample points. Three sub-slab and one indoor sample were collected using evacuated sample cells provided by Dr. Doug Hammond of University of Southern California (USC). The samples were collected in the same manner used to fill the summa canisters as described above. The filled cells were packed and shipped to USC for analysis. Additional indoor samples were collected using a commercially available passive system of activated carbon exposed to the indoor air for 48 to 72 hours. Per the manufacturer's instructions, the canisters were left open for a minimum of 48 hours then resealed and shipped to the laboratory for analysis. All samples collected by the canister method were collected in duplicate, including a blank.

2.3.6 Measurement of Cross-Foundation Pressure Gradient

The cross-foundation pressure gradient was measured during the sample collection program using a differential pressure transducer (Omega model PX274-01DI) and data logger (Omega model OM-CP-PROCESS101). The pressure transducer contains 2 pressure ports, one of which was open to the indoor atmosphere and one of which was isolated in the sub-slab atmosphere by tubing extending through the building slab and isolated from the indoor atmosphere. This apparatus allows for the direct measurement of the differential pressure between these two areas.



Pressure Transducer Installed to Measure Cross-Foundation Pressure Gradient.

2.3.7 Indoor Air Quality Survey

Prior to the collection of indoor air samples for VOC analysis, a survey of indoor air quality was conducted to identify any potential sources of VOCs in the building. A ppbRAE PID meter that allows for detection of total VOCs at ppb levels was used for the survey. The meter was placed into survey mode and carried throughout all of the accessible rooms in the demonstration building. No indoor VOC sources were detected through this survey.

2.4 Sample Analysis Methods

2.4.1 Geotechnical Analysis

Geotechnical soil samples were analyzed for bulk density, fraction organic carbon, moisture content / saturation, porosity, permeability, and hydraulic conductivity. Geotechnical analyses were performed by PTS Laboratories in Houston, Texas, according to applicable ASTM, EPA, and API methods as outlined in the Quality Assurance Project Plan (QAPP) included with the demonstration plan.

2.4.2 Groundwater Analysis

Groundwater samples were submitted to Severn Trent Laboratories in Houston, Texas, and analyzed for VOCs by USEPA Method SW846 8260B (8260B).

2.4.3 Gas and Vapor Sample Analysis

Gas samples were analyzed using an on-site mobile laboratory or an off-site fixed laboratory operated by H&P Mobile Geochemistry in Solana Beach, California. Samples analyzed on-site were analyzed for VOCs by 8260B using purge and trap sample delivery and a mass spectrometer (MS) detector. The majority of samples were analyzed with the MS detector in Selective Ion Monitoring (SIM) mode, allowing for detection limits comparable to those specified in the QAPP for USEPA Method TO-15. Samples for off-site analysis were collected in 400 mL mini summa canisters for analysis of VOCs by USEPA Method TO-15 and O_2 and CO_2 by ASTM Method 1945-96. As discussed in Section 4.1, the results of the TO-15 analyses were rejected due to data quality problems. Proposed remedial action to address this data rejection is provided in Section 5.5.

2.4.4 Radon Analysis

Radon samples collected by means of pre-weighed activated carbon canisters were analyzed using USEPA Method #402-R-93-004 079 and had a method detection limit of 0.4 pCi/L. Gasses collected in the evacuated cells for radon analysis were analyzed by Dr. Doug Hammond at the University of Southern California Department of Earth Sciences using the extraction method of Berelson, 1987 and the analysis method of Mathieu, 1998. This technique also generated a detection limit of 0.4 pCi/L.

3.0 Demonstration Results

The Altus AFB demonstration study resulted in the collection and analysis of a large number of samples, greatly exceeding the minimum number of analyses provided for in the demonstration plan. A summary of the sampling program completed for the study is shown below:

Overview of Altus AFB Sampling Program

	Number of Samples Collected								
Study Component	**Geotech**	**GW**	**Well Head Space**	**Soil Gas**	**Sub-Slab**	**Indoor**	**Ambient**	**SF_6 (Tracer Gas)**	**Radon**
Sample Point Inst.	9	-	-	-	-	-	-	-	-
Purge Study	-	-	4	16	4	-	-	-	-
Sample Event 1	-	8	3	11	3	3	3	-	-
Sample Event 2	-	3	8	11	3	3	3	-	-
Other VOC Samples	-	2	3	7	-	-	-	-	-
Tracer Gas Study	-	-	-	-	-	-	-	10	-
Radon Study	-	-	-	-	-	-	-	-	7

Note: Number of samples does not include QA/QC samples such as blanks and duplicates and does not include rejected TO-15 results.

In total, 124 sample analyses were completed for the Altus AFB demonstration, not including the rejected TO-15 analyses or the oxygen and carbon dioxide analyses. This total is 28% higher than the minimum of 97 analyses specified in the demonstration plan. If the proposed remedial action is completed for replacement of the rejected TO-15 data (see Section 5.5), an additional 24-35 VOC analyses will be completed depending on the number of monitoring wells that yield groundwater.

3.1 Shallow Geology

The local subsurface geology consists of clay, sandy clay, residual soils resulting from the weathering of shale, and weathered shale. The typical surficial soil is clay with some sand and silt present.

3.1.1 Field Observations

Investigation activities conducted in the vicinity of Building 418 for the demonstration study indicate that the shallow geology is comprised primarily of silty clay and clayey silts. Silty clay soil near the surface was dark brown in color and graded to brownish red or red at approximately 4 ft bgs, remaining red until the borings were terminated at 10.5 – 11.5 ft bgs. Soils encountered in the upgradient and midgradient areas were consistently silty clay extending to 10.5 ft bgs. The upgradient soils indicated a moist interval from 4.5 to 8 ft bgs. The midgradient soils indicated a moist interval from 7 to 9.5 ft bgs with dry silty clay below at both locations. The downgradient soils indicated silty clay extending down to 8 ft bgs and becoming moist at 6.5 ft bgs and soft at 7 ft bgs. The silty clay layer was underlain by a clayey silt layer saturated from 10 to 11.5 ft bgs. Coarse sand was observed in the saturated region from 10.5 to 10.75 ft bgs. Dry silty clay was observed at 11.5 feet at the termination of the boring. The clayey silt layer is apparently discontinuous as it was not observed in the borings advanced at the upgradient and midgradient sample locations. Geologic logs of the borings advanced in the 3 sample cluster areas are provided as Attachment B.

3.1.2 Results of Geotechnical Analyses

The results of the geotechnical analyses are provided on Table 1 and Figure 6. Geotechnical analyses showed only minor variation in soil properties with depth and location. The intrinsic permeability and hydraulic conductivity are consistent with silty clay soils.

3.2 Purge Study for Subsurface Gas Sample Points

On the first day of sample collection, a purge study was conducted on subsurface gas sampling points in order to refine and validate the sample collection procedures to be used for the demonstration study. The purge study had three objectives: i) determine the approximate concentration range for site COCs in subsurface environmental media, ii) evaluate the integrity of sample point seals and sampling lines, and iii) determine the appropriate purge volume to ensure collection of representative samples from each type of subsurface sampling point. Analysis of the purge study gas samples was conducted by 8260B using the on-site mobile lab which provided analytical results within two hours of sample collection. The analytical results for the purge study are provided on Table 2.

COC Concentration Range: Subsurface concentrations of PCE and TCE generally ranged from <5 to 200 ug/m^3. Based on this observed concentration range, the mass spectrometer used for sample quantitation was switched from normal operation to Selective Ion Monitoring (SIM) mode following analysis of the first 12 purge study samples. Operation in SIM mode decreases the 8260B quantitation limits from 1000 ug/m^3 to 5 ug/m^3. However, when operating in SIM mode, only a small and pre-designated list of chemicals can be quantified. PCE, TCE, cis-1,2-DCE, 1,2-trans-DCE, and vinyl chloride were selected for quantification by 8260B based on the detection of PCE, TCE and cis-1,2-DCE in groundwater during the RFI. Following analysis of the initial 12 purge study samples, SIM mode was used for all samples analyzed by the mobile lab with the exception of the SF_6 samples collected for the tracer gas study.

Evaluation of Sample Point Integrity: In order to verify the integrity of the sample points and the sample collection lines, a tracer gas (1,1-di-fluoroethane) was used at the ground surface during the collection of the purge study samples. 1,1-di-fluoroethane is the propellant used in duster spray and is available from office supply stores. Prior to sample collection, a paper towel was saturated with 1,1-di-fluoroethane and either placed within the sample point vault (created for the below-grade completion of the sample points) or wrapped around the sample collection lines. The detection of 1,1-di-fluoroethane in the collected sample indicates a leak in the sample point seal or the sampling lines.

Sample point integrity was evaluated for three soil gas sampling points (SG-5, SG-6, and SG-7) completed at depths of 1 ft bgs, 2 ft bgs, and 3 ft bgs, respectively. 1,1-di-fluoroethane was detected in samples collected from SG-5 (1 ft bgs), but not SG-6 or SG-7. For SG-5, 1,1-di-fluoroethane was detected in samples collected after purging of 2, 4, and 8 sample line purge volumes at a concentration range of 18 to 63 mg/m^3 but was not in the initial sample collected after purging a single line volume (see Table 2). This indicates a leak in the sample point seal or flow of 1,1-di-fluoroethane from the ground surface though the shallow soil rather than a leak in the sample collection lines. The leak detection method utilizing a paper towel saturated with 1,1-di-fluoroethane generally results in a 1,1-di-fluoroethane concentration in the sample point vault of 1 to 10% by volume (27,000 to 270,000 mg/m^3). As a result, the detected 1,1-di-fluoroethane concentration in the SG-5 samples (18 to 63 mg/m^3) represents only a very small leak of gases from the ground surface (0.007 to 0.2%). This minor surface dilution would not have significant impact on the measured concentrations of target COCs.

The evaluation of sample point seal integrity by use of tracer gas was discontinued following the switch to SIM mode for sample analysis because the concentration of 1,1-di-fluoroethane could not be quantified in SIM mode. However, throughout the sample collection program, the sample line integrity was verified by evaluating the ability of the sample lines to maintain a vacuum when not connected to the sampling point. In all cases, no leaks were found using this test method.

Purge Volume: In order to determine the appropriate purge volume for each type of sample point, samples were collected following purging of 1, 2, 4, and 8 sample line volumes. The calculations used to determine the sample line volumes are provided in Attachment E. Changes in target COC concentration were used for evaluation of the purge study results with the exception of sample points SG-5, SG-6, and SG-7. For these sample points (which were installed adjacent to a cluster of pine trees), a-pinene concentration was used for evaluation of the purge study results because no target COCs were detected in the samples. a-Pinene is a VOC associated with pine trees and was detected at relatively high concentrations in the samples from these samples points. Although no calibration curve was run for a-pinene, resulting in semi-quantitative concentration results, the relative concentrations detected in samples collected from the same sample point provided an effective method for evaluation of the appropriate purge volume.

Evaluation of the purge volume results indicates that the purging of 3 line volumes prior to sample collection results in the collection of samples with representative COC concentrations. For the six sample points evaluated (SG-4, SG-5, SG-6, SG-7, SS-1, and MW-3 head space), the COC concentrations measured in the samples generally increased between 1 and 2 purge volumes and were stable or slightly increasing from 2 to 8 purge volumes (see Table 2). COC concentrations were most stable in the sample points with the lowest total line volumes (i.e., SS-1 and SG-5). For some sample points with larger line volumes, COC concentrations increased from the 4 purge volume sample to the 8 purge volume sample. For these sample points, the large purge volumes may have resulted in vertical migration of COCs from depths with higher COC concentrations. Based on these results, a purge volume equal to 3 line volumes was selected as a volume sufficient to ensure thorough flushing of the sample collection lines but low enough to minimize the flow of gas in the subsurface around the sample collection point induced by the sample collection process.

3.3 Sample Event 1

Sample event 1 was completed on March 21 and 22, 2005 and involved collection of samples from all subsurface and above ground sampling points established for the demonstration. Groundwater samples were collected on March 21 and all gas samples were collected on March 22.

3.3.1 Groundwater Results

The groundwater monitoring network installed for the demonstration study consisted of three clusters of four vertically spaced monitoring wells with screen intervals of 3.5-4.5 ft bgs, 5.5-

6.5 ft bgs, 7.5-8.5 ft bgs, and 9.5-10.5 ft bgs (12 wells total, see Figure 3). In accordance with the workplan, monitoring well depths for the shallowest well in each cluster were chosen to straddle the top of the potentiometric surface in order to define the vertical concentration gradient near the top of the saturated zone. To determine the depth to water, water levels were measured in three existing nearby monitoring wells each screened from approximately 5 to 15 ft bgs. These wells showed a depth to water of approximately 5 ft bgs at the monitoring wells, corresponding to a depth of approximately 4 ft bgs at the demonstration building.

During the course of the demonstration study, only 5 of the 12 vertically-spaced monitoring wells yielded groundwater. Of these, two (MW-5 and MW-7) yielded significant volumes of water indicative of hydraulic connection to the shallow water-bearing unit while three (MW-3, MW-6, and MW-9) yielded smaller volumes of water. In the two higher yielding monitoring wells, the depth to groundwater was approximately 5 ft bgs indicating that the potentiometric surface was at approximately the expected elevation (i.e., 5 ft bgs compared to the expected 4 ft bgs). At the upgradient cluster, a shallower monitoring well yielded water while two deeper monitoring wells were dry indicating that, in some areas, shallow layers of more permeable saturated sediment are found above less permeable sediments that are dry.

The discontinuities in saturation observed in the upper 11 ft of sediments likely result from the wide variation of composition, degree of fracturing, weathering, and permeability that are characteristic of the shallow sediments at the site. The sediments of the upper water-bearing zone consist of silty and shaley clay interbeddeed with discontinuous lenses of silty sand and clayey silt that are derived from weathering of underlying Permian red beds. Although the vertically-spaced monitoring wells yielded fewer groundwater samples than anticipated in the demonstration plan, these wells still provided useful information concerning the distribution of groundwater within the shallow soils which is important for the understanding of COC migration at the site.

Groundwater samples were collected from the five demonstration site monitoring wells that yielded water. In addition, three existing monitoring wells (i.e., WL436, WL437, and WL643) with 10 ft screens located within 200 ft of the demonstration building were added to the demonstration sampling program in order to provide additional information concerning the current concentration of VOCs in the shallow groundwater. The analytical results for groundwater samples are provided on Attachment C, Table 3, and Figure 7. Concentrations of PCE ranged from <0.00023 to 0.039 mg/L, TCE ranged from <0.0001 to 0.14 mg/L, and cis-1,2-DCE ranged from <0.00027 to 0.038 mg/L. TCE was the most commonly detected COC with detectable concentrations present in 7 of 8 groundwater samples.

3.3.2 Well Headspace Results

For sample event 1, well headspace samples were collected from the shallowest monitoring well that yielded water in each cluster (i.e., three samples total). PCE was detected in one sample (MW-3, 12 ug/m^3), TCE was detected in all three samples (15 – 57 ug/m^3) and cis-1,2-DCE was detected in one sample (MW-9, 270 ug/m^3). The analytical results for well headspace samples are provided on Table 4 and Figure 8.

3.3.3 Soil Gas Results

For sample event 1, soil gas samples were collected from 11 of 12 soil gas points. No sample was collected from SG-2 (screened at 2 ft. bgs in the upgradient cluster) due to the presence of water in the sample point. PCE was detected at 9 of 11 locations (7 – 95 ug/m^3), TCE was detected at 3 of 11 locations (5-14 ug/m^3) and cis-1,2-DCE was detected at 0 of 11 locations (i.e., <5 ug/m^3). PCE and TCE concentrations were higher in soil gas samples collected below the building compared to samples collected adjacent to the building. The analytical results for soil gas samples are provided on Table 5 and Figure 8.

3.3.4 Sub-Slab Results

For sample event 1, sub-slab gas samples were collected from all three sub-slab sample points. PCE (16-130 ug/m^3) and TCE (8-39 ug/m^3) were detected at all three locations while cis-1,2-DCE was not detected (i.e., <5 ug/m^3). The analytical results for sub-slab samples are provided on Table 6 and Figure 8.

3.3.5 Indoor and Ambient Results

For sample event 1, three indoor and three ambient air samples were collected. PCE, TCE, and cis-1,2-DCE were not detected in any of these samples (i.e., <5 ug/m^3). The analytical results for indoor and ambient samples are provided on Table 7 and Figure 8.

3.4 Sample Event 2

Sample event 2 was completed on March 23 and 24, 2005 and involved collection of samples from all subsurface sampling points and above ground sampling locations established for the demonstration. Groundwater samples and ambient, indoor, and sub-slab gas samples were collected on March 23 and soil gas and well headspace samples were collected on March 24. For sample event 2, the scope of the well headspace sampling program was expanded beyond the demonstration plan in order to provide additional information on the vertical distribution of VOCs in deep soil gas.

3.4.1 Groundwater Results

For sample event 2, only three of the demonstration monitoring wells yielded sufficient water to support sampling. Groundwater samples were collected from these three demonstration site monitoring wells. Concentrations of PCE ranged from <0.00023 mg/L to 0.0033 mg/L, TCE ranged from <0.0001 mg/L to 0.15 mg/L, and cis-1,2-DCE ranged from 0.00064 to

0.014 mg/L. The analytical results for groundwater samples are provided on Attachment C, Table 3, and Figure 7.

3.4.2 Well Headspace Results

For sample event 2, well headspace samples were collected from 10 of the 12 demonstration site monitoring wells. Although the demonstration plan specified well head space samples from only the shallowest well in each cluster, the additional sampling was conducted in order to provide a deeper vertical profile of soil vapor concentrations. PCE was detected at 8 of 10 locations (5-450 ug/m^3), TCE was detected at 9 of 10 locations (7 – 480 ug/m^3) and cis-1,2-DCE was detected at 6 of 10 locations (46-180 ug/m^3). The analytical results for well headspace samples are provided on Table 4 and Figure 8.

3.4.3 Soil Gas Results

For sample event 2, soil gas samples were collected from 11 of 12 soil gas points. No sample was collected from SG-2 (screened at 2 ft. bgs in the upgradient cluster) due to the presence of water in the sample point. PCE was detected at 9 of 11 locations (6 – 56 ug/m^3), TCE was detected at 3 of 11 locations (6-13 ug/m^3) and cis-1,2-DCE was detected at 0 of 11 locations (i.e., <5 ug.m^3). The analytical results for soil gas samples are provided on Table 5 and Figure 8.

3.4.4 Sub-Slab Results

For sample event 2, sub-slab samples were collected from all three sub-slab sample points. PCE (16-140 ug/m^3) and TCE (6-49 ug/m^3) were detected at all three locations while cis-1,2-DCE was not detected (i.e., <5 ug.m^3). The analytical results for sub-slab samples are provided on Table 6 and Figure 8.

3.4.5 Indoor and Ambient Results

For sample event 2, three indoor and three ambient air samples were collected. PCE was detected in one sample (Indoor 1, 7 ug/m^3) while TCE, and cis 1,2-DCE were not detected in any of these samples. The analytical results for indoor and ambient samples are provided on Table 7 and Figure 8.

3.5 Miscellaneous VOC Analyses

In order to characterize potential sources of soil gas COCs other than groundwater, one gas sample was collected from a sewer line running parallel to the demonstration building on the northeast side about 100 ft from the building (see Table 8 and Figure 8). The gas sample was collected approximately 6 inches above the water level which was approximately 8 ft bgs. This sample contained 10 ug/m^3 PCE, 200 ug/m^3 TCE, and 47 ug/m^3 cis-1,2-DCE. The modest COC concentrations measured in this sample indicate that the sewer line is not a significant source of the VOCs measured at the demonstration building.

In addition, three well headspace samples and eight soil gas samples were collected on March 23, 2005, between sample events 1 and 2. These samples were collected as part of the comparison of sample collection methods (see Section 4.2). Analytical results for these samples are provided on Tables 4 and 5. The VOC concentrations in these samples were similar to those measured during sample events 1 and 2 indicating that i) comparable results were obtained using different sample collection methods, and ii) repeated sample collection over a 4-day period did not alter the distribution of VOCs within the subsurface.

3.6 Oxygen and Carbon Dioxide Analyses

In order to evaluate the occurrence of aerobic or anaerobic biodegradation in the unsaturated soil column, samples collected by summa canister were analyzed for oxygen and carbon dioxide (see Table 9). Oxygen concentrations were uniformly high throughout the subsurface ranging in concentration from 19 to 25% by volume. Carbon dioxide concentrations ranged from <0.1 to 5.1% and generally increased with depth indicating aerobic biodegradation at lower depths in the soil column.

3.7 Tracer Gas Study: Building Air Exchange Rate

In order to determine the air exchange rate in the demonstration building (i.e., the rate at which building air is replaced by ambient air), a tracer gas study was conducted inside the building on March 22 and 23 as follows:

1) On the morning of March 22, a cylinder of SF_6 was set up in a central room (see Figure 9) and set to release SF_6 at a flow rate of 150 mL/min. A constant release rate was continued for >20 hours in order to allow SF_6 concentrations in the building to achieve steady state.

2) On the morning and afternoon of March 23, SF_6 samples were collected from various locations throughout the demonstration building in order to determine the steady state SF_6 concentration in the building. The release of SF_6 was continued until after the second sample event was completed. The building HVAC system was operated normally during the tracer gas study and this system provided a continuous circulation of air through the building.

The first SF_6 sample event was conducted at the beginning of the day in order to determine building air exchange during the overnight period and the second sample event was conducted at the end of the day to determine the air exchange rate during operating hours. Three samples were collected for the first event and seven samples were collected for the second event.

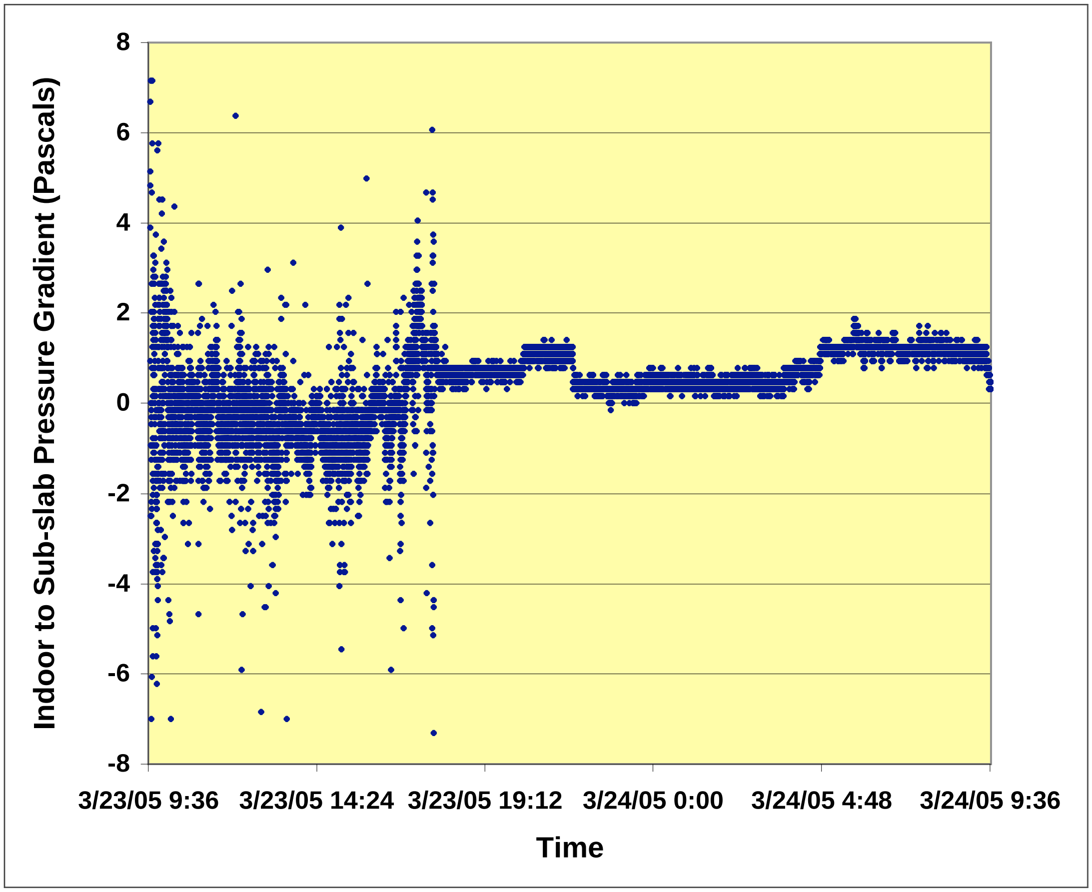
SF_6 concentrations were relatively uniform throughout the building, ranging in concentration from 1.6 ppmv to 9.3 ppmv (see Table 10 and Figure 9). The concentration was highest in the release room and was lowest at either end of the building. Overall, the SF_6 concentration was somewhat higher for the second sample event indicating a lower air exchange rate during daytime hours. Calculation of the building air exchange rate is shown in Attachment E and the results are discussed in Section 4.3.

3.8 Analysis of Radon Concentrations

In order to determine a site-specific slab attenuation factor (i.e., the dilution of COCs from sub-slab to indoor air), radon samples were collected from the three sub-slab and three indoor air sampling locations. Three sub-slab and one indoor gas samples were collected using evacuated cells provided by Dr. Doug Hammond of USC. These samples were returned to Dr. Hammond by overnight delivery for analysis. In addition, three indoor samples were collected using charcoal samplers widely available for home radon testing. Sub-slab radon concentrations ranged from 479 to 1092 pCi/L while indoor radon concentrations ranged from <0.4 pCi/L to 0.4 pCi/L (see Table 11 and Figure 10).

3.9 Cross-Foundation Pressure Gradient

In order to evaluate the impact of pressure gradients on the movement of chemicals between the subsurface and indoor air, the cross-foundation differential pressure was measured over the course of the demonstration study. The differential pressure measurements indicate low pressure gradients between the building interior and the sub-slab area with pressure gradients generally ranging from -2 to 2 pascals. Pressure gradients were more variable during business hours when the building was occupied, likely due to the opening and closing of building doors, which, combined with the 10 to 20 mph ambient winds prevalent during the field program, caused variations in indoor pressure. The slight positive pressure observed during non-business hours is typical for commercial buildings and would serve to minimize the flow of VOCs and other gasses from the sub-slab to indoor air. Measured pressure gradients over a typical 24-hour period are shown below.



Typical Indoor to Sub-Slab Pressure Gradients.
Note: Positive pressure gradient indicates indoor pressure is higher than sub-slab pressure.

4.0 Data Interpretation

4.1 Evaluation of Data Quality

For the purpose of data usability evaluation, analytical results have been evaluated in four groups: i) geotechnical samples, ii) groundwater samples, iii) gas samples analyzed at the on-site mobile laboratory by 8260B, and iv) gas samples analyzed off-site by Method TO-15 for VOCs and by Method ASTM 1945 for CO_2 and O_2. The results of the data usability evaluation are presented below.

4.1.1 Geotechnical Data

All geotechnical samples collected for the demonstration were analyzed by PTS Laboratories in Houston, Texas. All of these samples met the criteria for all quality objectives outlined in the QAPP based on custody procedures, holding time and temperature, sampling procedures, accuracy, and completeness.

Finding: Data useable, 100% of samples meet data quality objectives.

4.1.2 Groundwater Data

All groundwater samples collected for the demonstration were analyzed by Severn Trent Laboratories in Houston, Texas. These samples met the criteria for all quality objectives outlined in the QAPP with one exception. A sample cooler shipped with wet ice was received at the laboratory with a temperature of 0.9° C, slightly below the target range of 2° to 6° C. Deviations in holding temperature, such as this one, which are below the target range but above freezing, are not expected to affect the analytical results. As a result, the samples in this cooler were determined to meet the data quality objective (DQO) for holding temperature. Duplicate analyses were performed at least once per 20 samples and all relative percent differences (RPDs) were within the 30% limit for demonstration of acceptable method precision. All trip blanks, field blanks, and laboratory blanks were non-detect for all compounds of interest. All laboratory standards and spiked samples were within recovery limits for demonstration of acceptable accuracy. The laboratory selected other clients' samples to perform as the Matrix Spike / Matrix Spike Duplicate. 100% of the groundwater samples collected for analysis were analyzed and generated usable data. In one instance, a sample (MW-1, 3/25/05) was indicated on the chain-of-custody that was not received at the laboratory; this was determined to be an error on the sampler's part and not indicative of an actual sample.

Finding: Data useable, 100% of samples meet data quality objectives.

4.1.3 Gas Samples: USEPA SW846-8260B, Mobile Lab

All gas samples collected for the demonstration were analyzed in an on-site mobile laboratory by 8260B. Gas analysis by the 8260B method was added after the QAPP was prepared, and therefore no DQOs were established for these analyses. As a result, the data have been evaluated by comparing the results to the DQOs identified for the TO-15 analysis. Duplicate analyses were performed at least once per 20 samples and all RPDs were within the 30% limit for demonstration of acceptable method precision. All field blanks, line blanks, and method blanks analyzed by the mobile laboratory were non-detect for all compounds of interest. 100% of the gas samples collected for analysis by the mobile laboratory were analyzed and generated usable data. As shown below, the 8260B-SIM reporting limit was slightly greater than the TO-15 DQO for three of five target COCs, however, this difference was not determined to undermine the data usability.

Comparison of TO-15 and 8260B-SIM Reporting Limits

Chemical	TO-15 Reporting Limit	8260B-SIM Reporting Limit
PCE	6.78 ug/m^3	5.0 ug/m^3
TCE	5.37 ug/m^3	5.0 ug/m^3
cis-1,2-DCE	4.04 ug/m^3	5.0 ug/m^3
1,2-trans-DCE	4.04 ug/m^3	5.0 ug/m^3
Vinyl Chloride	2.60 ug/m^3	5.0 ug/m^3

On-site gas analysis was conducted following the CA-EPA (DTSC)/LA-RWCB soil gas guidelines which consist of a multi-point calibration curve, opening standard, opening blank and adding surrogates to each sample. The guidelines do not require MS/MSDs nor closing standards if compounds are detected during the run. Duplicate sample analysis is performed on provided field duplicates only, no matrix spike or matrix spike duplicate analysis is performed.

Finding: Data useable, 100% of samples meet data quality objectives except for a slight exceedance of TO-15 reporting limits.

4.1.4 Gas Samples: USEPA TO-15 and ASTM 1945 (O_2 and CO_2), Fixed Lab

In addition to on-site analysis by 8260B, a sub-set of samples was collected in duplicate for off-site analysis of VOCs by TO-15 and CO_2 and O_2 by ASTM 1945. The trip blank sample that accompanied the summa canisters was found to contain several VOCs at concentrations that exceeded the reporting limits established in the QAPP. In addition, all of the samples were found to contain detectable levels of VOCs which were not expected to be present at the site (e.g., acetone and trimethylbenzene). Finally, VOC concentrations were found to differ significantly between field duplicate samples (i.e., RPD >30%). Based on the data quality evaluation, it appears that the summa canisters were not properly cleaned prior to use for this demonstration and, as a result, the TO-15 analytical results are not useable. The rejected analytical results are provided on Attachment D and proposed remedial action to address rejection of TO-15 results is described in Section 5.5.

As shown in the summary table below, the samples do meet the DQOs for ASTM 1945 and as a result, the CO_2 and O_2 results have been found to be useable.

Finding: TO-15 results rejected. Proposed remedial action to address rejection of TO-15 results is described in Section 5.5. ASTM 1945 (O_2 and CO_2) results useable, 100% of samples meet data quality objectives.

Summary of Data Evaluation Results

Data Quality Objective	Results of Data Quality Evaluation				
	Groundwater	Gas-8260B	Gas-TO-15*	O_2 and CO_2	Geotechnical
Custody Procedures	Acceptable*	Acceptable	Acceptable	Acceptable	Acceptable
Holding Time	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
Temperature on Arrival	Acceptable*	NA	NA	NA	Acceptable
Blank Analysis	Acceptable	Acceptable	Not Acceptable	Acceptable	NA
Lab Control Standards	Acceptable	NA	Not Acceptable	Acceptable	NA
Duplicate Sample	Acceptable	Acceptable	Not Acceptable	Acceptable	NA
Matrix Spike/MSD	Acceptable	NA	NA	NA	NA
Surrogate Recovery	Acceptable	Acceptable	NA	Acceptable	NA
Sampling Procedures	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
Field Instrumentation	Acceptable	NA	NA	NA	NA
Accuracy Assessment	Acceptable	NA	Not Acceptable	NA	Acceptable
Precision Assessment	Acceptable	Acceptable	Not Acceptable	Acceptable	NA
Completeness Assessment	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
Overall Data Usability	**100%**	**100%**	**Data Rejected**	**100%**	**100%**

Acceptable= This DQO was evaluated and found to have met the requirements outlined in the QAPP. Not Acceptable = This DQO was evaluated and found to be deficient in meeting the requirements specified by the QAPP, NA = DQO is not applicable to the indicated method. * = See explanation in associated text.

4.2 Comparability of Sample Collection Methods: Soil Gas Sampling Points

In order to determine the impact of sample collection method on sample results, three sample collection methods were evaluated for outdoor soil gas points (whole casing purge, 1/4 inch tubing, and Nylaflow tubing) and two sample collection methods were evaluated for well headspace samples (1/4 inch tubing, and Nylaflow tubing). These sample collection methods are explained in Section 2.3 and depicted on Figure 5. These sample collection methods represent different trade-offs between minimizing sample line purge volume and assurance that all stagnant air has been removed from the sample point prior to sample collection.

For each sample collection method, three line volumes were purged prior to sample collection, however, the volume of the sample line varied depending on the sample collection method resulting in differing total purge volumes.

Sample Line Volume for Sample Collection Methods

Sample Collection Method	Line Volume (mL/ft)
Whole Casing (1/2” PVC)	60
1/4 Inch Tubing	10
Nylaflow Tubing	1

Note: Total line volume (mL) = line volume (mL/ft) x sample point depth (ft).

The “whole casing purge” and “1/4 inch tubing” sample collection methods require relatively large purge volumes in order to remove three sample line volumes prior to sample collection. This larger purge volume ensures that stagnant air at the sample point is removed, however, the larger purge volume also results in more air flow around the sample point leading to less certainty concerning the representativeness of the sample for the specific sample point location. In contrast, the "Nylaflow" sample collection requires only a very small purge volume, potentially leaving stagnant air in the sample point, but ensuring that the sample itself is drawn from air at the sample point location.

The three sample collection methods were compared for 6 soil gas sample points (see Table 5). The COC concentrations measured using the three methods generally varied by less than 2x, consistent with the range of variability observed between duplicate samples. In addition, no consistent trend in COC concentration was observed between the three sample collection methods. Two sample collection methods (1/4 inch tubing, and Nylaflow tubing) were also compared for the collection of well headspace samples from MW-3 (see Tables 2 and 4). Although the COC concentrations in the sample collected on March 22nd using 1/4 inch tubing were approximately 1/3rd of the COC concentrations in the March 23 and 24 samples collected using Nylaflow tubing, the COC concentrations in samples collected using Nylaflow tubing were consistent with the COC concentrations measured during the purge volume study conducted on March 21 using 1/4 inch tubing. Taken as a whole, these results indicate that comparable results are obtained using the three different sample collection methods evaluated. Based on this finding, Nylaflow tubing is recommended for future sample collection due to the simplicity of this sample collection method.

Finding: The three sample collection methods used for the collection of subsurface gas samples yielded comparable results indicating that all three methods yield representative samples.

4.3 Building Air Exchange Rate

The results of the SF_6 tracer gas study have been used to calculate a site-specific air exchange rate for the demonstration building. The calculations, provided in Attachment E, indicate an air exchange rate of 19/day for the morning sample event and 16/day for the evening sample event.

Results of Tracer Gas Study

Sample Event	Time Period Evaluated	Building Air Exchange Rate	Fresh Air Entry Rate	Expected Fresh Air Entry Rate From HVAC System
Morning	Overnight	19/day	1,200 ft^3/min	>1,140 ft^3/min
Evening	Daytime	16/day	1,000 ft^3/min	1,140 ft^3/min

Note: Calculations provided in Attachment E.

Based on a building volume of 89,600 ft^3, this corresponds to a flow rate of 1200 ft^3/min of fresh air into the building in the morning and 1000 ft^3/min in the evening. The building manger reports that the HVAC system circulates air at a maximum rate of 7,615 ft^3/min. The HVAC system draws 15% fresh air when ambient temperatures are above 55˚F and draws a higher fraction of fresh air at lower ambient temperatures in order to minimize HVAC system cooling requirements. On the day of the tracer gas study (March 23), ambient temperatures were in the mid 40s overnight and in the upper 50s during the day. As a result, the HVAC system was expected to supply approximately 1140 ft^3/min of fresh air during the day and a larger volume during the overnight period. These expected fresh air inflow rates are similar to those measured through the tracer gas test (i.e., 1200 ft^3/min for the overnight period and 1000 ft^3/min for the daytime period) providing increased confidence in the accuracy of the tracer gas study results. In addition, this analysis indicates that the building air exchange rate is unlikely to drop below 16/day when the HVAC circulating system is operating continuously, as was observed during the field program.

Finding: Analysis of the tracer gas results yields a building air exchange rate of 16 to 19/day, a range consistent with the reported operation of the building HVAC system.

4.4 Vapor Intrusion Impact

Determination of the presence or absence of a vapor intrusion impact at the demonstration building is a primary performance criterion for the demonstration project.

4.4.1 Measured Indoor VOC Concentrations

For the Altus AFB demonstration, all COC concentrations were non-detect (<5 ug/m^3) in 5 of 6 indoor air samples collected. In one sample, PCE was detected at a concentration of 7 ug/m^3, greater than the USEPA indoor air concentration limit for 10^{-6} risk (0.81 ug/m^3), but within the range of commonly observed indoor air background concentrations (0.29 – 28 ug/m^3; McHugh, 2004). Although all gas sample blanks yielded non-detect results, a detection of 7 ug/m^3 PCE could still be consistent with a laboratory artifact due to the low detected concentration relative to the method reporting limit (i.e., 7 ug/m^3 vs. 5 ug/m^3). Alternatively, the low concentration of PCE in one indoor air sample could be associated with an indoor source such as dry-cleaned clothing. However, the result does not appear to be indicative of a vapor intrusion impacts based on the observation that i) PCE was detected in only one of six indoor air samples and ii) the detected PCE concentration was significantly higher than the estimated indoor PCE concentration due to vapor intrusion based on the evaluation of the radon measurements discussed below.

4.4.2 Estimated Indoor VOC Concentrations Based on Radon Analyses

As an alternative to the direct measurement of indoor VOCs, radon analyses have been used to further evaluate the potential for a vapor intrusion impact to the demonstration building. The radon results can be used to calculate a site-specific slab attenuation factor that describes the dilution that occurs as VOCs move from the sub-slab environment to indoor air. Radon analyses provide an accurate measure of sub-slab to indoor air attenuation due to the absence of indoor radon sources other than vapor intrusion.

Because the tracer gas study indicated that air inside the demonstration building is well mixed, average sub-slab and indoor air radon concentrations were used to determine the slab attenuation factors as follows:

$$AF_{SS\text{-}IA} = C_{IA}/C_{SS}$$

Where:
$AF_{SS\text{-}IA}$ = Sub-slab to indoor air attenuation factor (unitless)
C_{IA} = Concentration of radon in indoor air
(0.4 pCi/L, average indoor result from Table 11)
C_{SS} = Concentration of radon in sub-slab
(833 pCi/L, average sub-slab result from Table 11)

$AF_{SS\text{-}IA}$ = 0.4 pCi/L / 833 pCi/L = 0.00048

In calculation of the average indoor air concentration, the detection limit was used for non-detect results. This evaluation indicates that COC concentrations decrease by 2000x from sub-slab to indoor air.

To evaluate whether a VOC vapor intrusion impact has occurred, indoor air VOC concentrations have been estimated based on average sub-slab VOC concentrations and the slab attenuation measured for radon. Based on the results of six sub-slab samples collected for the demonstration study (see Table 6), the average sub-slab PCE and TCE concentrations are 59 and 20 ug/m^3, respectively. Using these concentrations, the expected average indoor air concentrations are 0.028 and 0.0096 ug/m^3, respectively for PCE and TCE, below the USEPA indoor air concentration limit for 10^{-6} risk (0.81 and 0.022 ug/m^3; USEPA, 2002).

Based on the analyses conducted, no vapor intrusion impact was present in the building at the time of the Altus demonstration (March 21-24, 2005). However, estimated indoor TCE concentrations were approximately 40% of the USEPA indoor air limit. As a result, variations in VOC transport along the vapor intrusion pathway could result in exceedances of the USEPA vapor intrusion limits at other times. Factors which could influence the transport of VOCs along the vapor intrusion pathway include: i) variations in TCE concentration in shallow groundwater, ii) increased diffusion of TCE through the soil column during dry weather, iii) increased flow through the building foundation due to negative building pressure, or iv) changes in building ventilation rates.

Finding: An evaluation of both measured and estimated indoor VOC concentrations indicates that a vapor intrusion impact was not present for Building 418 at the time of the Atlus field demonstration. Additional sampling would be required to characterize temporal variability in vapor intrusion. This additional evaluation is planned for one of the three demonstration sites.

4.5 Movement of VOCs Across Key Interfaces

Use of mass flux to evaluate the movement of COCs across key interfaces along the vapor intrusion pathway is a secondary performance criterion. By evaluating the changes in mass flux for each COC along the vapor intrusion pathway, the impact of each interface on the migration of these COCs can be better understood. Mass flux calculations using the Altus AFB demonstration dataset are presented in Attachment E and the results are discussed below.

Mass Flux Along the Vapor Intrusion Pathway: Altus Demonstration Site

Environmental Medium or Interface		Mass Flux (ug/day)		
		PCE	TCE	cis-1,2-DCE
F_{GW1}:	Groundwater, upgradient of demonstration building (upper 2 ft)	9,600	14,700	9,300
F_{GW-SG}:	Groundwater to deep soil gas	Not calculated	Not calculated	Not calculated
F_{SG}:	Deep soil gas to sub-slab	118 - 265	18 - 467	62-143
F_{SS-IA}:	Through building foundation	1160	397	<99

Note: The dataset obtained did not support the calculation of groundwater to deep soil gas mass flux due to the limited data on vertical concentration gradients within groundwater.

As shown above, the mass flux within the top 2 feet of the water column is approximately 10 to 1000 times higher than the mass flux in the soil column under the demonstration building or mass flux through the building foundation. This indicates that approximately 90 – 99% of VOC mass remains in the shallow groundwater as it passes under the demonstration building. These results are consistent with the presence of a large dissolved groundwater plume at the site in which VOC concentrations decrease slowly with distance downgradient.

In the absence of soil column biodegradation, the mass flux through the soil column under the demonstration building is expected to be equal to the mass flux through the building foundation. With biodegradation, mass flux through the soil column would be greater than mass flux through the building foundation due to the loss of mass within the soil column. For TCE, the mass flux through the soil column is similar to the mass flux through the building foundation, indicating no biodegradation in the soil column. For PCE, the mass flux through the soil column is 4 to 10 times lower than the mass flux through the building foundation. This observed difference in mass flux for PCE is likely due to variability and uncertainty in the COC concentration measurements and other parameter values used in the mass flux calculations.

In contrast to TCE and PCE, the mass flux of cis-1,2-DCE through the building foundation is lower than the mass flux through the soil column. Cis-1,2-DCE was detected in groundwater and well headspace samples, but was not detected in any soil gas or sub-slab sample. This result indicates that biodegradation is likely preventing the vertical migration of cis-1,2-DCE through the soil column at elevations of less than 4 ft bgs. Unlike PCE and TCE, cis-1,2-DCE is known to biodegrade under aerobic conditions. The high concentrations of oxygen and modestly elevated levels of carbon dioxide found in the deeper soil gas samples support the conclusion that aerobic biodegradation of cis-1,2-DCE is occurring in the soil column.

Finding: The mass flux of COCs decreases significantly from the groundwater to the soil column. For PCE and TCE, the mass flux through the soil column is similar to the mass flux through the building foundation. For cis,1-2-DCE, aerobic biodegradation prevents detectable concentrations from reaching the shallow unsaturated soils.

4.6 Spatial and Temporal Variability in VOC Concentrations

The characterization of spatial and temporal variability in VOC concentration is a secondary performance criterion for the demonstration. Spatial variability was characterized through the collection of samples from three sampling clusters located around the demonstration building, upgradient, midgradient, and downgradient (see Figure 8). Short-term temporal variability was characterized through the collection of samples from all sample points for two sample events conducted within a single week.

4.6.1 Spatial Variability

Significant spatial variability was observed within all environmental media.

Groundwater: Spatial variability was observed in the depth of the groundwater-bearing unit. Two wells in the downgradient cluster penetrated the groundwater-bearing unit (i.e., MW-7 and MW-5 with screen intervals of 7.5-8.5 ft bgs and 9.5-10.5 ft bgs) while no wells in the upgradient and midgradient clusters penetrated the groundwater-bearing unit (see Figure 3). This indicates a variability of more than two feet in the depth to the groundwater-bearing unit in the vicinity of the demonstration building. In addition, COC concentrations within groundwater were highly variable with TCE concentration varying by >100x and PCE concentrations varying by > 10x. However, the limited number of groundwater samples obtained prevented a statistical evaluation of spatial variability of COC concentrations in groundwater.

Subsurface Gas Samples: High spatial variability was observed in COC concentrations measured in subsurface gas samples collected at the same elevation within the upgradient, midgradient, and downgradient clusters. COC concentrations typically varied by 5x to 10x between the three cluster (see Attachment F.1). In addition, the coefficient of variation was typically greater than one, indicating high variability.

Within the unsaturated soil column, the vertical distribution of COCs is more uniform at the midgradient sample cluster where the soil gas sample points were installed under the demonstration building compared to the upgradient and downgradient clusters which were installed outside, adjacent to the building (see Figure 8). This difference may be due to the presense of perched groundwater at several depths between the ground surface and the shallow groundwater-bearing unit (see Figure 3). These perched groundwater zones are likely attributable to surface infiltration and may serve to impede the vertical migration of COCs through the soil column. These perched groundwater layers appear to be absent under the demonstration building, likely due to the absence of infiltration in this area. The absence of perched groundwater may allow for more uniform vertical distribution of COCs under the building foundation.

Above Ground Gas Samples: Little spatial variability was observed in COC concentrations between above-ground sampling points primarily due to the prevalence of non-detect concentrations at these sample points (see Figure 8 and Attachment F.1).

Finding: *Based on the results of the first demonstration, spatial variability may be a significant source of uncertainty in vapor intrusion evaluation. Placement of soil gas sample points below (rather than adjacent to) the building foundation may reduce the variability in COC concentrations in soil gas.*

4.6.2 Temporal Variability

Low temporal variability was observed in COC concentrations between the two sample events conducted on separate days within a single week as part of the demonstration study. Out of 56 paired analyses completed for the two sampling events, 46 (82%) showed a relative percent difference (RPD) of <30%, indicating that these analyses would satisfy the data quality objective for duplicate samples. 8 paired analyses (14%) showed an RPD of 30 to 100% while only 2 (3%) showed an RPD of >100%. The statistical analysis of temporal variability is provided as Attachment F and is summarized below.

Evaluation of Temporal Variability in COC Concentrations

Environmental Medium	Number of Paired Analyses: Event 1 and Event 2			
	Total	RPD < 30%	RPD 30-100%	RPD > 100%
Groundwater	9	9	0	0
Well Headspace	9	4	3	2
Soil Gas	20	16	4	0
Sub-slab	6	6	0	0
Indoor	6	5	1	0
Ambient	6	6	0	0

Note: A paired analysis is one COC measured at one sample location during both sample events. Analysis includes PCE, TCE, and cis-1,2-DCE in groundwater and well headspace samples and PCE and TCE in soil gas, sub-slab, indoor, and ambient samples.

These results provide a preliminary indication that short-term temporal variability in COC concentrations is not a major source of uncertainty in the evaluation of the vapor intrusion pathway. Following completion of data collection from all three demonstration sites, additional statistical analyses will be completed to examine potential differences in temporal variability between environmental media.

Finding: Based on the results of the first demonstration, short-term temporal variability is not a major source on uncertainty in vapor intrusion evaluation.

4.7 Attenuation Factors

Evaluation of attenuation factors is a secondary performance criterion for the demonstration study. As discussed in Section 4.4.2, sub-slab and indoor radon measurements have been used to determine the sub-slab to indoor attenuation factor. As shown in Attachment E, attenuation factors for other environmental media have been determined using the PCE and TCE concentrations measured in those media and estimated in indoor air. The calculated attenuation factors are summarized below.

Attenuation Factors for Altus Site Demonstration Building

Pathway	Measured Attenuation Factor		USEPA Default Attenuation Factor
	PCE	TCE	
Sub-slab to Indoor	4.8×10^{-4} (1)	4.8×10^{-4} (1)	0.1
Deep Soil Gas to Indoor (4 – 10 ft bgs)	1.6×10^{-4}	2.7×10^{-5}	0.01
Groundwater to Indoor	9.4×10^{-7}	3.7×10^{-7}	1.0×10^{-3}

Note:
1) Sub-slab to indoor air attenuation factor determined based on results of radon analyses (see Section 4.4.2). Indoor air concentrations of PCE and TCE estimated based on measured sub-slab concentrations and radon attenuation factor.

This evaluation indicates that the default USEPA attenuation factors significantly over-estimate the potential for vapor intrusion impacts for the Altus AFB site demonstration building. The observed attenuation is 60 to 2700 times greater than implied by the USEPA defaults.

Based on the analysis of attenuation factors, significant dilution of VOCs occurs at both the groundwater/soil gas interface and the building foundation. The sub-slab to indoor air attenuation factor is 200 times lower than the USEPA default. In addition, this values is about 10 times lower than the average attenuation factor of 0.003 measured in a previous radon study of 10 residential homes (Mosley, 2004). The relatively high dilution through the building foundation measured for the demonstration building is likely attributable to the relatively high building air exchange rate (i.e., 16/day to 19/day compared to the USEPA default of 4/day) and the slightly positive building pressure typically maintained by the building HVAC system.

The default USEPA attenuation factors for groundwater and deep soil gas imply a 10x decrease in VOC concentration from groundwater to deep soil gas, significantly less dilution than was observed at the Altus AFB demonstration site. However, little field data is available to indicate the typical dilution across this interface at corrective action sites. A comparison of groundwater and deep soil gas attenuation factors for the demonstration site indicates that roughly 100x dilution of VOCs was measured across the groundwater/soil gas interface at the demonstration site (i.e., the groundwater to indoor air attenuation factor is 100x lower than the deep soil gas to indoor air attenuation factor). The evaluation of additional demonstration sites will provide an indication of the site-specific characteristics that influence the observed VOC dilution across the groundwater interface.

Finding: Attenuation factors for the Altus AFB demonstration site are lower than the USEPA default values indicating higher levels of VOC dilution along the vapor intrusion pathway at this site. The highest levels of VOC dilution were found across the groundwater interface and across the building foundation.

4.8 Site Physical Characteristics

The influence of site physical characteristics on VOC migration along the vapor intrusion pathway is a secondary performance criterion for the demonstration project. As shown on Table 1 and Figure 6, relatively little variation in soil physical characteristics were observed between sample locations and sample depths. As a result, the influence of soil characteristics on VOC migration cannot be evaluated based on the data from this single demonstration site. The influence of soil, building, and other site physical characteristics on vapor intrusion will be evaluated following completion of all three site demonstrations.

Finding: The influence of site physical characteristics on vapor intrusion cannot be adequately evaluated based on the results from a single demonstration site.

4.9 Reliable Vapor Intrusion Investigation Approach

The identification of a reliable vapor intrusion investigation approach based on a limited sub-set of the demonstration data is a primary performance criterion. The evaluation of data subsets based on environmental media and vertical profiles is discussed below.

4.9.1 Individual Environmental Media

Although the evaluation of the entire demonstration dataset indicates that no vapor intrusion impact has occurred in the demonstration building (see Section 4.4), the evaluation of the data subset for any single environmental medium using the USEPA vapor intrusion guidance (USEPA, 2002) would provide a false positive indication of a vapor intrusion impact.

Evaluation of Potential Vapor Intrusion Using Data for Individual Environmental Media

Environmental Medium	Representative Concentration	USEPA 2002 Screening Limit (10^{-6} Risk)	Potential Vapor Intrusion Impact Indicated?	Accuracy
Indoor Air	PCE: 5 ug/m^3 (1) TCE: <5 ug/m^3	PCE: 0.81 ug/m^3 TCE: 0.022 ug/m^3	Yes	False Positive
Sub-slab	PCE: 59 ug/m^3 TCE: 20 ug/m^3	PCE: 8.1 ug/m^3 TCE: 0.22 ug/m^3	Yes	False Positive
Deep Soil Gas	PCE: 178 ug/m^3 TCE: 353 ug/m^3	PCE: 81 ug/m^3 TCE: 2.2 ug/m^3	Yes	False Positive
Groundwater	PCE: 0.039 mg/L TCE: 0.060 mg/L	PCE: 0.005 mg/L TCE: 0.005 mg/L	Yes	False Positive

Note:
1) Representative indoor air concentration based on the detection of PCE in one of six indoor air samples at a concentration of 7 ug/m^3. Based on evaluation of the full dataset, this detection is attributed to background indoor sources or a laboratory false positive detection.

In contrast, when the radon analyses are used to determine a site-specific sub-slab to indoor air attenuation factor, the sub-slab PCE and TCE dataset indicates no vapor intrusion impact on the demonstration building (see Section 4.4). Based on this analysis, sub-slab VOC concentration data combined with sub-slab and indoor radon analysis represents the most reliable data subset for the evaluation of vapor intrusion impacts. Note, however, that this preliminary conclusion is based on the analysis of only one of the three planned demonstration sites and may be modified based on the results of the two remaining demonstration sites.

An evaluation of data subset cost effectiveness will be completed following data collection from all three demonstration sites.

4.9.2 Vertical COC Profiles

Vertical COC profiles from individual sample locations (i.e., upgradient, midgradient, or downgradient) also represent potential datasets for the evaluation of vapor intrusion. Although the vertical profiles are important for understanding the migration of COCs along the vapor intrusion pathway, the spatial variability observed between sample locations indicates that a single vertical profile would not provide a reliable indicator of vapor intrusion impact.

Finding: The results from the first demonstration site suggest that sub-slab VOC concentration data combined with sub-slab and indoor radon concentration data provides an accurate evaluation of vapor intrusion impact.

5.0 Lessons Learned and Preliminary Conclusions

5.1 Sample Point Location and Installation

Overall the design of the sample collection network proved to be effective for understanding the distribution of VOCs along the vapor intrusion pathway at the demonstration site. With the exception of the dry groundwater monitoring wells, all sample points yielded samples representative of the targeted environmental medium.

Although 7 of 12 monitoring wells did not yield groundwater during the demonstration field program, these sample points did provide important information concerning vertical distribution of groundwater at the site and, in addition, these sample points yielded well headspace samples that provided additional information on the vertical distribution of VOCs in deep soil gas. Of the five monitoring wells that did yield water, three wells appear to be screened above the shallow water-bearing unit based on the very low yield of groundwater in these wells (see Figure 3). The VOC concentrations in these three wells were much lower than the VOC concentration in the two higher yielding wells, further suggesting that these wells are not directly linked to the water-bearing unit and indicating that the relatively stagnant water above the water-bearing unit likely serves as a low permeability barrier to the vertical diffusion of VOCs from groundwater to deep soil gas.

The most significant limitation of the groundwater monitoring network installed for the Altus AFB demonstration was the absence of monitoring wells screened in the water-bearing unit at two of the three vertical clusters. This absence prevented the measurement of VOC concentrations at the top of the water-bearing unit at multiple locations directly adjacent to the demonstration building.

<u>Recommendation</u>: *No changes are recommended for the design and location of ambient, indoor, sub-slab, and soil gas sample points, however, a change is recommended for the installation of the vertical groundwater monitoring points. For the Altus AFB demonstration site, the vertical monitoring wells were installed using 2 ft vertical spacing starting from the elevation of the potentiometric surface (see Figure 3). If confining conditions are present at future demonstration sites, the vertical spacing of the monitoring wells should be increased, if necessary, to ensure that at least one monitoring well at each cluster is installed within the shallow groundwater-bearing unit.*

5.2 Sample Collection Methods for Subsurface Samples

For the Altus AFB demonstration site, different sample collection methods requiring higher or lower purge volume prior to sample collection yielded comparable results (see Section 4.2). This indicates that sample results are not sensitive to purge volume for the sample collection methods evaluated.

<u>Recommendation</u>: Sample collection should be standardized to low volume tubing. However, the impact of total purge volume on sample result should be evaluated at the remaining demonstration sites to determine the applicability of the preliminary results to varying site conditions.

5.3 Sample and Analysis Methods for Indoor and Ambient Air Samples

Although the analysis of indoor air samples by 8260B-SIM achieved detection limits equal to the method-specified reporting limits for TO-15, these detection limits are higher than the reporting limits obtained by some laboratories providing analysis of indoor air samples by TO-15. In addition, the detection limits obtained for this demonstration are significantly higher than the indoor air limits for the site COCs provided in USEPA vapor intrusion guidance (USEPA, 2002). As a result, lower analytical lower detection limits for indoor air samples would provide additional information concerning the presence or absence of a vapor intrusion impact at the site and concerning the sub-slab-to-indoor-air attenuation factors.

<u>Recommendation</u>: For future indoor air sampling at Altus and the other test sites, we recommend the use of 6-L Summas and analysis at a laboratory that can achieve lower detection limits. We recommend that one ambient air sample also be analyzed using this method in order to obtain comparable analytical results. We anticipate detection limits in the range of 1 ug/m^3 (i.e., 0.1 to 0.2 ppbv) or better for these samples.

5.4 Data Collection Plan

With the exception of the TO-15 data, the data set obtained from the demonstration program was sufficient to satisfy the primary and secondary demonstration performance objectives. As discussed in Section 4, this data set has been used to obtain a detailed understanding of VOC migration along the vapor intrusion pathway at the Altus AFB demonstration site. In addition, the data set has been used for the preliminary identification of a limited site investigation approach that will accurately identify vapor intrusion impacts (see Section 4.9). It is anticipated that the collection of similar data sets from the remaining demonstration sites will serve to identify site physical characteristics that significantly impact the movement of VOCs along the vapor intrusion pathway. This will support the development of screening criteria that serve to identify high risk and low risk vapor intrusion sites based on site physical characteristics.

<u>Recommendation</u>: The basic sample collection program from the Altus AFB Demonstration Plan should be maintained for the remaining demonstration sites (i.e., no changes are recommended for the sample point locations and minimum number of samples collected). This sample plan can be implemented using either an on-site or off-site laboratory for the analysis of gas samples. If feasible based on cost and logistical consideration, an on-site laboratory should be used for the analysis of gas samples with confirmation by off-site TO-15 analysis. The use of an on-site laboratory providing real-time analytical results at the Altus AFB site allowed in-field

modification of the sample collection program which significantly increased the understanding of VOC distribution and vapor intrusion processes at the Altus AFB demonstration site.

Proposed remedial action to address the rejection of the TO-15 data for the Altus AFB demonstration is discussed in Section 5.5.

5.5 Proposed Remedial Action for the Rejected TO-15 Data

As discussed in Section 4.1, the TO-15 analytical results did not satisfy the data quality objectives for the demonstration and were rejected. Although the data set obtained from the remaining analyses supported a detailed understanding of vapor intrusion processes at the site, the rejection of the TO-15 data resulted in the loss of useful information including:

Lower Quantitation Limits: TO-15 yields slightly lower quantitation limits for 3 of the 5 target COCs, providing some additional information on the distribution of site VOCs at low concentration sample points.

Longer Analyte List: TO-15 allows for the quantification of 35 VOCs, compared to the 5 VOCs quantified by 8260B when operating in SIM mode. Although all of the known groundwater VOCs were quantified by 8260B, the quantification of additional VOCs could potentially increase the understanding of VOC sources and movement within the demonstration building.

Confirmation of 8260 Results: Although the 8260B results satisfied the DQOs for the demonstration, the TO-15 results (which were collected as duplicates of selected 8260B samples) would have provided additional confirmation of the quality of the 8260B results.

In order to address the deficiencies created by the rejection of the TO-15 results, an additional sampling event is proposed for the Altus AFB site. The analytical laboratory (H&P Mobile Geochemistry) has agreed to cover the cost of the sample collection and analysis by TO-15 of one sample from each gas sample collection point (i.e., ambient, indoor, sub-slab, soil gas, and well headspace, plus associated QA/QC samples). In addition, Groundwater Services, Inc. will cover the cost of groundwater sample collection and analysis in order to provide an additional complete data set of VOC analyses. For this sampling event, each summa canister will be tested prior to sample collection to verify the absence of residual VOCs.

This remedial action will address two of the three deficiencies created by the rejection of the existing TO-15 data (i.e., lower quantitation limits and longer analyte list). In addition, the remedial action will generate an additional complete VOC dataset (i.e., VOC sample results from all demonstration program sample points) which can be used to further evaluate the temporal variability in VOC distribution at the site. This supplemental sample event is proposed for the week of August 29, 2005 (based on building access considerations) and would be conducted in addition to the evaluation of temporal variability planned following completion of the three demonstration site field programs.

Recommendation: In order to compensate for the rejection of the TO-15 data, conduct a supplemental sampling event with TO-15 analyses for gas samples and 8260B analyses for groundwater samples. The cost of this supplemental sampling event will be covered by H&P Mobile Geochemistry and Groundwater Services, Inc.

6.0 References

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GROUNDWATER SERVICES, INC.

Environmental Security Technology Certification Program
(ESTCP)

RESULTS AND LESSONS LEARNED INTERIM REPORT: ALTUS AFB SITE

TABLES

GROUNDWATER
SERVICES, INC.

TABLE 1
RESULTS OF GEOTECHNICAL ANALYSES
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

SAMPLE ID.	SAMPLE DEPTH	BULK DENSITY	FRACTION ORGANIC CARBON	POROSITY			INTRINSIC PERMEABILITY TO WATER	NATIVE HYDRAULIC CONDUCTIVITY
				TOTAL	AIR FILLED	WATER FILLED	25 PSI CONFINING STRESS	
Units	ft.	kg/L	g/g	%Vb	%Vb	%	cm^2	cm/s
MW-2	1-2	1.49	5.55E-03	43.1	13.5	69	4.18E-12	4.05E-07
MW-2	4-5	1.72	1.20E-03	35.1	9.2	74	4.24E-13	4.15E-08
MW-2	7-8	1.6	1.60E-03	40.4	13.9	65	1.87E-12	1.86E-07
MW-6	2-3	1.62	9.20E-03	38.1	11.2	71	2.48E-12	2.45E-07
MW-6	5.5-6.5	1.63	1.50E-03	39.6	14.5	63	1.18E-11	1.18E-06
MW-6	7.5-8.5	1.65	7.90E-04	38.6	10	74	3.35E-12	3.28E-07
MW-10	2-3	1.6	5.05E-03	39.1	13.5	65	2.85E-12	2.76E-07
MW-10	5-6	1.67	1.15E-03	36.7	8.6	77	7.14E-13	6.97E-08
MW-10	7-8	1.63	9.90E-03	39.1	9.7	75	2.30E-12	2.25E-07

Notes:
1) Analysis performed by PTS Laboratories, Houston, Texas.
2) Fraction Organic Carbon determined by Walkley-Black method, intrinsic permeability and hydraulic conductivity determined by EPA 9100, vol. moisture content determined by ASTM D2216 & API RP40, all other analyses by API RP40.
3) All sample orientations were vertical.
4) Vb = bulk volume.

TABLE 2
RESULTS FOR PURGE STUDY FOR SUB-SLAB, SOIL GAS, AND WELL HEADSPACE SAMPLE POINTS
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

SAMPLE LOCATION:	SG-5				SG-6				SG-7			
SCREEN DEPTH (ft bgs):	1				2				3			
SAMPLE TYPE:	Soil-gas				Soil-gas				Soil-gas			
SAMPLE DATE:	03/21/05				03/21/05				03/21/05			
SAMPLE COLLECTION METHOD:	Whole Casing Purge				Whole Casing Purge				Whole Casing Purge			
CASING or LINE VOLUME (cc):	60				120				180			
LINE VOLUMES PURGED (cc):	1	2	4	8	1	2	4	8	1	2	4	8
ANALYSIS METHOD:	8260	8260	8260	8260	8260	8260	8260	8260	8260	8260	8260	8260
COMPOUND	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Compounds of Interest												
1,1-di-fluoroethane (tracer)	< 10000	**18000**	**54000**	**63000**	< 10000	< 10000	< 10000	< 10000	< 10000	< 10000	< 10000	< 10000
Trichloroethene (TCE)	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000
Tetrachloroethene (PCE)	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000
cis-1,2-dichloroethene	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000
trans-1,2-dichlororethene	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000
Vinyl chloride	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000	< 1000
a-pinene (3)	**5686000**	NA	**6006000**	**5314000**	**1351000**	**1907000**	**2348000**	**2697000**	**472000**	**219000**	**534000**	**2910000**

SAMPLE LOCATION:	SS-1				SG-4				MW-3			
SCREEN DEPTH (ft bgs):	0.7				4				5.5-6.5			
SAMPLE TYPE:	Sub-Slab				Soil-gas				Well Headspace			
SAMPLE DATE:	03/21/05				03/21/05				03/21/05			
SAMPLE COLLECTION METHOD:	Threaded Cap				Whole Casing Purge				1/4 Inch Tubing			
CASING or LINE VOLUME (cc):	10				240				60			
LINE VOLUMES PURGED (cc):	4	10	20	30	1	2	4	8	1	2	4	8
ANALYSIS METHOD:	8260 SIM	8260 SIM	8260 SIM	8260 SIM	8260 SIM	8260 SIM	8260 SIM	8260 SIM	8260 SIM	8260 SIM	8260 SIM	8260 SIM
COMPOUND	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Compounds of Interest												
Trichloroethene (TCE)	**30**	**39**	**49**	**55**	**20**	< 5	< 5	< 5	**62**	**100**	**150**	**130**
Tetrachloroethene (PCE)	**63**	**97**	**120**	**150**	**7**	**5**	**7**	**5**	**9**	**11**	**22**	**25**
cis-1,2-dichloroethene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	**6**	< 5
trans-1,2-dichlororethene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Vinyl chloride	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5

NOTES:
1. Samples were analyzed with on-site instrumentation by H&P Mobile Geochemistry, Solana Beach, California by Method 8260B.
2. Detected analytes are presented in **bold** type.
3. Results for a-pinene are semi-quantitative due to absence of calibration curve for a-pinene.
4. < = not detected at detection limit shown.

TABLE 3
RESULTS OF GROUNDWATER ANALYSES: SUMMARY OF DETECTED COMPOUNDS
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

						DUPLICATE		*DUPLICATE*	
SAMPLE LOCATION:	MW-3	MW-5	MW-5	MW-6	MW-7	MW-7	MW-7	MW-7	MW-9
SCREEN INTERVAL (ft):	5.5-6.5	9.5-10.5	9.5-10.5	5.5-6.5	7.5-8.5	7.5-8.5	7.5-8.5	7.5-8.5	9.5-10.5
SAMPLE TYPE:	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
SAMPLE DATE:	3/21/2005	3/21/2005	3/23/2005	3/21/2005	3/21/2005	3/21/2005	3/23/2005	3/23/2005	3/21/2005
COMPOUND	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Compounds of Interest									
cis-1,2-Dichloroethene	< 0.00027	**0.012**	**0.012**	< 0.00027	**0.015**	**0.018**	**0.014**	**0.014**	**0.0073**
trans-1,2-Dichloroethene	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	**0.0010**	<0.00015	<0.00015	<0.00015
Tetrachloroethene	< 0.00023	**0.0019**	**0.0030**	< 0.00023	**0.0030**	**0.0033**	**0.0033**	**0.0031**	< 0.00023
Toluene	**0.0042**	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016
Trichloroethene	**0.0022**	**0.10**	**0.11**	**0.0019**	**0.14**	**0.14**	**0.14**	**0.15**	< 0.0001
Acetone	**0.011**	**0.036**	**0.0064**	**0.025**	**0.010**	**0.011**	**0.0042**	**0.0034**	**0.0088**

SAMPLE LOCATION:	MW-9	WL-436	WL-437	WL-643	SG-2	SG-2	Trip Blank	Field Blank
SCREEN INTERVAL (ft):	9.5-10.5	6.3-16.3	6.3-16.3	4.4-14.4	1.9-2	1.9-2	NA	NA
SAMPLE TYPE:	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
SAMPLE DATE:	3/23/2005	3/22/2005	3/22/2005	3/22/2005	3/23/2005	3/24/2005	3/22/2005	3/21/2005
COMPOUND	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Compounds of Interest								
cis-1,2-Dichloroethene	**0.0064**	**0.038**	< 0.00027	< 0.00027	< 0.00027	< 0.00027	<0.00027	<0.00027
trans-1,2-Dichloroethene	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015
Tetrachloroethene	< 0.00023	**0.039**	< 0.00023	< 0.00023	< 0.00023	< 0.00023	< 0.00023	< 0.00023
Toluene	<0.00016	<0.00016	<0.00016	<0.00016	**0.0028**	<0.00016	<0.00016	<0.00016
Trichloroethene	< 0.0001	**0.060**	**0.0058**	**0.0090**	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Acetone	**0.0043**	<0.00053	<0.00053	<0.00053	**0.0074**	**0.0025**	<0.00053	**0.0029**

Notes:
1. All groundwater samples were analyzed by Severn Trent Laboratories, Inc., Houston, Texas by Method 8260B.
2. Screen intervals indicated for WL-436, and WL-437 are estimated based on knowledge of other wells in the area.
3. Detected analytes are presented in bold type.
4. < = not detected at detection limit shown.
5. NA = not applicable.

GROUNDWATER SERVICES, INC.

TABLE 4
RESULTS OF WELL HEADSPACE ANALYSES: 8260B - SIM
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

SAMPLE LOCATION:	MW-1	MW-2	MW-3	MW-3	MW-3	MW-4	MW-5
SCREEN DEPTH (ft bgs):	9.5-10.5	7.5-8.5	5.5-6.5	5.5-6.5	5.5-6.5	3.5-4.5	9.5-10.5
SAMPLE DATE:	3/24/2005	3/24/2005	3/22/2005	3/23/2005	3/24/2005	3/24/2005	3/23/2005
SAMPLE COLLECTION METHOD:	Nylaflow	Nylaflow	1/4 Inch Tub.	Nylaflow	Nylaflow	Nylaflow	Nylaflow
COMPOUND	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Compounds of Interest							
Trichloroethene (TCE)	**390**	**450**	**56**	**140**	**180**	**8**	**480**
Tetrachloroethene (PCE)	**450**	**130**	**12**	**31**	**40**	**10**	< 5
cis-1,2-dichloroethene	**71**	**46**	< 5	**14**	< 5	< 5	**180**
trans-1,2-dichlororethene	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Vinyl chloride	**6**	< 5	< 5	< 5	< 5	< 5	< 5

SAMPLE LOCATION:	MW-6	MW-6	MW-7	MW-8	MW-9	MW-9	MW-10
SCREEN DEPTH (ft bgs):	5.5-6.5	5.5-6.5	7.5-8.5	3.5-4.5	9.5-10.5	9.5-10.5	7.5-8.5
SAMPLE DATE:	3/22/2005	3/24/2005	3/23/2005	3/24/2005	3/22/2005	3/24/2005	3/24/2005
SAMPLE COLLECTION METHOD:	Nylaflow	Nylaflow	Nylaflow	Nylaflow	Nylaflow	Nylaflow	Nylaflow
COMPOUND	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Compounds of Interest							
Trichloroethene (TCE)	**57**	**43**	**380**	< 5	**15**	**7**	**130**
Tetrachloroethene (PCE)	< 5	**7**	**5**	**10**	< 5	< 5	**20**
cis-1,2-dichloroethene	< 5	< 5	**170**	< 5	**270**	**100**	**130**
trans-1,2-dichlororethene	< 5	< 5	**10**	< 5	< 5	< 5	< 5
Vinyl chloride	< 5	< 5	< 5	< 5	**23**	**16**	**5**

NOTES:
1. Samples were analyzed with on-site instrumentation by H&P Mobile Geochemistry, Solana Beach, California by Method 8260B.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown.

TABLE 5
RESULTS OF SOIL-GAS ANALYSES: 8260B-SIM
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

							DUPLICATE		*DUPLICATE*		
SAMPLE LOCATION:	SG-1	SG-1	SG-3	SG-3	SG-3	SG-4	SG-4	SG-4	SG-4	SG-4	SG-5
SCREEN DEPTH (ft bgs):	1	1	3	3	3	4	4	4	4	4	1
SAMPLE DATE:	3/22/2005	3/23/2005	3/22/2005	3/23/2005	3/24/2005	3/22/2005	3/22/2005	3/23/2005	3/23/2005	3/24/2005	3/22/2005
SAMPLE COLLECTION METHOD:	Whole Casing	Nylaflow	Whole Casing	Nylaflow	1/4 Inch Tub.	Whole Casing	Whole Casing	Nylaflow	Nylaflow	1/4 Inch Tub.	Whole Casing
COMPOUND	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Compounds of Interest											
Trichloroethene (TCE)	< 5	< 5	< 5	**6**	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Tetrachloroethene (PCE)	**7**	< 5	< 5	**9**	< 5	< 5	< 5	**7**	**6**	< 5	**16**
cis-1,2-dichloroethene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
trans-1,2-dichlororethene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Vinyl chloride	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5

SAMPLE LOCATION:	SG-5	SG-5	SG-6	SG-6	SG-6	SG-7	SG-7	SG-7	SG-8	SG-8	SG-8
SCREEN DEPTH (ft bgs):	1	1	2	2	2	3	3	3	4	4	4
SAMPLE DATE:	3/23/2005	3/24/2005	3/22/2005	3/23/2005	3/24/2005	3/22/2005	3/23/2005	3/24/2005	3/22/2005	3/23/2005	3/24/2005
SAMPLE COLLECTION METHOD:	Nylaflow	1/4 Inch Tub.	Whole Casing	Nylaflow	1/4 Inch Tub.	Whole Casing	Nylaflow	1/4 Inch Tub.	Whole Casing	Nylaflow	1/4 Inch Tub.
COMPOUND	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Compounds of Interest											
Trichloroethene (TCE)	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Tetrachloroethene (PCE)	**8**	**7**	**13**	**7**	**7**	**10**	< 5	< 5	**9**	**9**	**7**
cis-1,2-dichloroethene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
trans-1,2-dichlororethene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Vinyl chloride	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5

	DUPLICATE								
SAMPLE LOCATION:	SG-8	SG-9	SG-9	SG-10	SG-10	SG-11	SG-11	SG-12	SG-12
SCREEN DEPTH (ft bgs):	4	1	1	2	2	3	3	4	4
SAMPLE DATE:	3/24/2005	3/22/2005	3/24/2005	3/22/2005	3/24/2005	3/22/2005	3/24/2005	3/22/2005	3/24/2005
COMPOUND	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Compounds of Interest									
Trichloroethene (TCE)	**6**	**5**	< 5	< 5	< 5	**14**	**13**	**6**	**8**
Tetrachloroethene (PCE)	**6**	**23**	**22**	**27**	**24**	**54**	**49**	**95**	**56**
cis-1,2-dichloroethene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
trans-1,2-dichlororethene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Vinyl chloride	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5

NOTES:
1. Samples were analyzed with on-site instrumentation by H&P Mobile Geochemistry, Solana Beach, California by Method 8260B.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown.

TABLE 6
RESULTS OF SUB-SLAB ANALYSES: 8260B-SIM
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

				DUPLICATE				*DUPLICATE*
SAMPLE LOCATION:	SS-1	SS-1	SS-2	SS-2	SS-2	SS-3	SS-3	SS-3
SAMPLE DATE:	3/22/2005	3/23/2005	3/22/2005	3/22/2005	3/23/2005	3/22/2005	3/23/2005	3/23/2005
COMPOUND	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Compounds of Interest								
Trichloroethene (TCE)	**39**	**49**	**8**	**12**	**9**	**8**	**7**	**6**
Tetrachloroethene (PCE)	**130**	**140**	**16**	**31**	**18**	**22**	**18**	**16**
cis-1,2-dichloroethene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
trans-1,2-dichlororethene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Vinyl chloride	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5

NOTES:
1. Samples were analyzed with on-site instrumentation by H&P Mobile Geochemistry, Solana Beach, California by Method 8260B.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown.

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TABLE 7
RESULTS OF INDOOR AND AMBIENT AIR ANALYSES: 8260B-SIM
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

SAMPLE LOCATION:	Indoor 1	Indoor 1	Indoor 2	Indoor 2	Indoor 3	Indoor 3
SAMPLE DATE:	3/22/2005	3/23/2005	3/22/2005	3/23/2005	3/22/2005	3/23/2005
COMPOUND	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Compounds of Interest						
Trichloroethene (TCE)	< 5	< 5	< 5	< 5	< 5	< 5
Tetrachloroethene (PCE)	< 5	**7**	< 5	< 5	< 5	< 5
cis-1,2-dichloroethene	< 5	< 5	< 5	< 5	< 5	< 5
trans-1,2-dichlororethene	< 5	< 5	< 5	< 5	< 5	< 5
Vinyl chloride	< 5	< 5	< 5	< 5	< 5	< 5

SAMPLE LOCATION:	Ambient 1	Ambient 1	Ambient 2	Ambient 2	Ambient 3	Ambient 3
SAMPLE DATE:	3/22/2005	3/23/2005	3/22/2005	3/23/2005	3/22/2005	3/23/2005
COMPOUND	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Compounds of Interest						
Trichloroethene (TCE)	< 5	< 5	< 5	< 5	< 5	< 5
Tetrachloroethene (PCE)	< 5	< 5	< 5	< 5	< 5	< 5
cis-1,2-dichloroethene	< 5	< 5	< 5	< 5	< 5	< 5
trans-1,2-dichlororethene	< 5	< 5	< 5	< 5	< 5	< 5
Vinyl chloride	< 5	< 5	< 5	< 5	< 5	< 5

NOTES:
1. Samples were analyzed with on-site instrumentation by H&P Mobile Geochemistry, Solana Beach, California by Method 8260B.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown.

GROUNDWATER SERVICES, INC.

TABLE 8
RESULTS OF BLANKS AND MISCELLANEOUS GAS SAMPLE ANALYSES: 8260B & 8260B-SIM
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

SAMPLE LOCATION:	Sewer	Line Blank	Line Blank	Line Blank	Line Blank	Line Blank	Line Blank
SAMPLE DATE:	3/23/2005	3/21/2005	3/21/2005	3/22/2005	3/23/2005	3/24/2005	3/24/2005
ANALYSIS METHOD:	8260B-SIM	8260B	8260B	8260B-SIM	8260B-SIM	8260B-SIM	8260B-SIM
COMPOUND	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Compounds of Interest							
Trichloroethene (TCE)	**200**	< 1000	< 1000	< 5	< 5	< 5	< 5
Tetrachloroethene (PCE)	**10**	< 1000	< 1000	< 5	< 5	**5**	< 5
cis-1,2-dichloroethene	**47**	< 1000	< 1000	< 5	< 5	< 5	< 5
trans-1,2-dichlororethene	< 5	< 1000	< 1000	< 5	< 5	< 5	< 5
Vinyl chloride	< 5	< 1000	< 1000	< 5	< 5	< 5	< 5

NOTES:
1. Samples were analyzed with on-site instrumentation by H&P Mobile Geochemistry, Solana Beach, California by Method 8260B.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown.

TABLE 9
RESULTS OF OXYGEN AND CARBON DIOXIDE ANALYSES
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

						DUPLICATE				
SAMPLE LOCATION:	SG-1	SG-1	SG-3	SG-3	SG-4	SG-4	SG-4	SG-5	SG-5	SG-6
SCREEN DEPTH (ft bgs):	1	1	3	3	4	4	4	1	1	2
SAMPLE DATE:	3/22/2005	3/24/2005	3/22/2005	3/24/2005	3/22/2005	3/22/2005	3/24/2005	3/22/2005	3/24/2005	3/22/2005
COMPOUND	%	%	%	%	%	%	%	%	%	%
Compounds of Interest										
Carbon dioxide	0.6	0.1	0.5	<0.1	1.2	0.3	1.3	1	1.3	1.9
Oxygen	24	24	25	24	24	25	23	22	23	24

						DUPLICATE				
SAMPLE LOCATION:	SG-6	SG-7	SG-7	SG-8	SG-8	SG-8	SG-9	SG-10	SG-11	SG-12
CASING DEPTH (ft bgs):	2	3	3	4	4	4	1	2	3	4
SAMPLE DATE:	3/24/2005	3/22/2005	3/24/2005	3/22/2005	3/24/2005	3/24/2005	3/22/2005	3/22/2005	3/22/2005	3/22/2005
COMPOUND	%	%	%	%	%	%	%	%	%	%
Compounds of Interest										
Carbon dioxide	2.9	2.4	4.5	1.9	5.1	3.1	0.7	1.4	1.9	1.8
Oxygen	22	23	20	23	19	22	24	25	24	23

SAMPLE LOCATION:	Sub-slab 1	Sub-slab 2	Sub-slab 2	Sub-slab 3	Sub-slab 3	Ambient Air	Indoor 2
CASING DEPTH (ft bgs):	0.7	0.7	0.7	0.7	0.7	NA	NA
SAMPLE DATE:	3/22/2005	3/22/2005	3/23/2005	3/22/2005	3/23/2005	3/22/2005	3/22/2005
COMPOUND	%	%	%	%	%	%	%
Compounds of Interest							
Carbon dioxide	1.2	2.4	2.6	1.2	0.6	1.1	0.6
Oxygen	24	23	22	24	24	22	24

NOTES:
1. Samples were analyzed by H&P Mobile Geochemistry, Solana Beach, California in accordance with ASTM-1945-96 methodology.
2. NA = not applicable.

GROUNDWATER SERVICES, INC.

TABLE 10
RESULTS OF SULFUR HEXAFLUORIDE TRACER GAS ANALYSES
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

SAMPLE LOCATION:	Indoor 1	Indoor 2	Indoor 3	*DUPLICATE* Indoor 3
SAMPLE DATE:	3/23/2005	3/23/2005	3/23/2005	3/23/2005
SAMPLE TIME:	0750	0750	0751	0751
COMPOUND	ppmv	ppmv	ppmv	ppmv
Compounds of Interest				
Sulfur Hexafluoride (SF6)	2.7	1.6	7.4	9.3

SAMPLE LOCATION:	Indoor 1	Indoor 2	Indoor 3	Indoor 4	Indoor 5	Indoor 6	Indoor 7
SAMPLE DATE:	3/23/2005	3/23/2005	3/23/2005	3/23/2005	3/23/2005	3/23/2005	3/23/2005
SAMPLE TIME:	1536	1540	1539	1535	1537	1538	1541
COMPOUND	ppmv	ppmv	ppmv	ppmv	ppmv	ppmv	ppmv
Compounds of Interest							
Sulfur Hexafluoride (SF6)	4.5	3.2	8.3	3.8	5.8	6	2.5

1. Samples were analyzed with on-site instrumentation by H&P Mobile Geochemistry, Solana Beach, California by Method 8260B.
2. SF6 release start time: 3/22/05 at 0830, Average SF6 release rate: 140 mL/min.

GROUNDWATER SERVICES, INC.

TABLE 11
RESULTS OF RADON ANALYSES
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

				Duplicate			*DUPLICATE*
SAMPLE LOCATION:	SS-1	SS-2	SS-3	SS-3	Indoor 3	Indoor-1	Indoor-1
SAMPLE TYPE:	Radon cell	Radon cell	Radon cell	Radon cell	Radon cell	Canister	Canister
SAMPLE DATE:	3/22/2005	3/22/2005	3/22/2005	3/22/2005	3/22/2005	3/25/2005	3/25/2005
COMPOUND	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L
Compound of Interest							
Radon	**1092**	**958**	**479**	**480**	**0.4**	<0.4	<0.4

		DUPLICATE		*DUPLICATE*		*DUPLICATE*
SAMPLE LOCATION:	SS-2	SS-2	SS-3	SS-3	Blank	Blank
SAMPLE TYPE:	Canister	Canister	Canister	Canister	Canister	Canister
SAMPLE DATE:	3/25/2005	3/25/2005	3/25/2005	3/25/2005	3/25/2005	3/25/2005
COMPOUND	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L
Compound of Interest						
Radon	<0.4	<0.4	**0.4**	<0.4	<0.4	<0.4

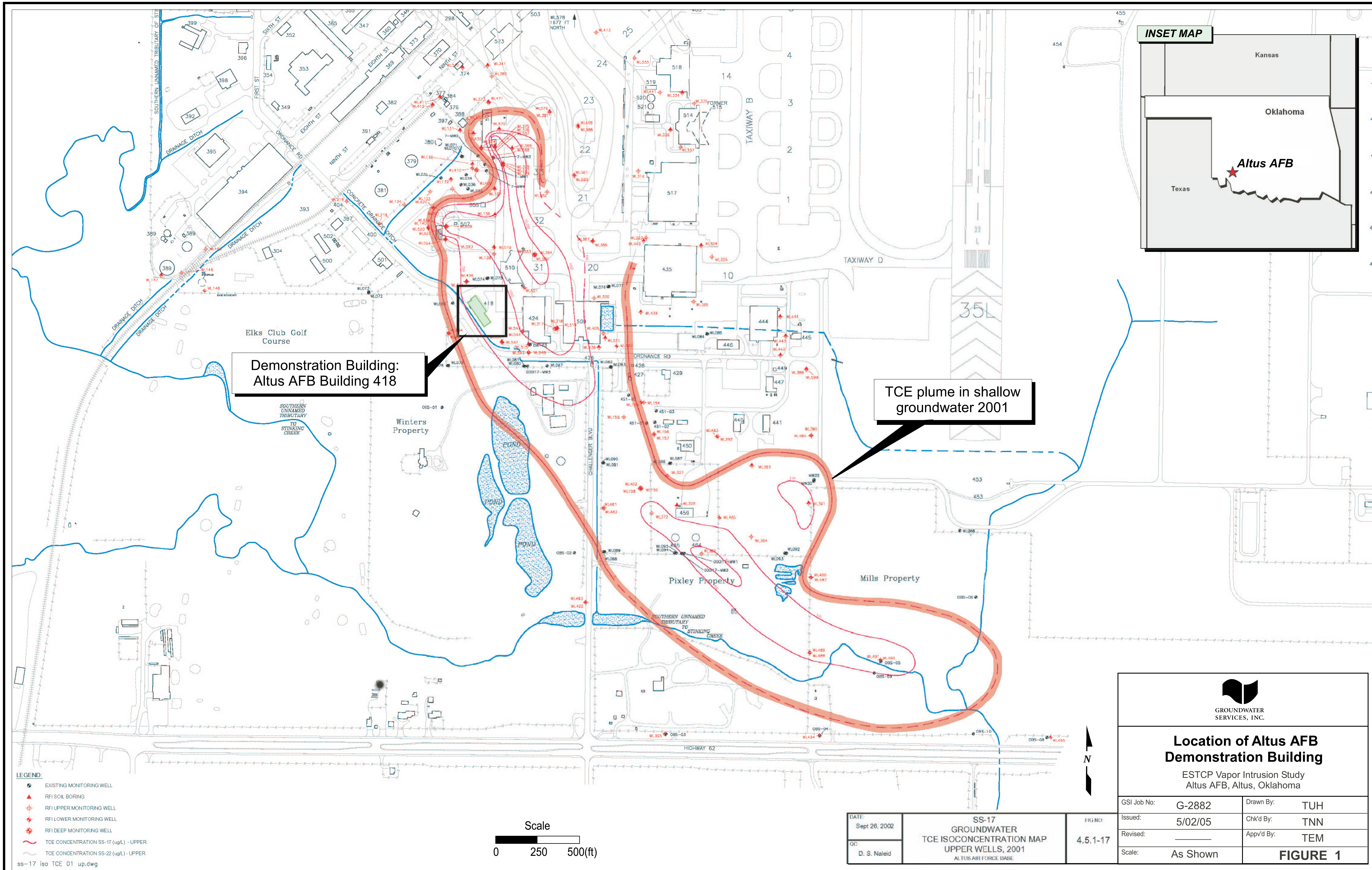
NOTES:
1. Radon cell samples were analyzed by Doug Hammond, University of Southern California.
2. Canister samples were analyzed by Accustar Labs, Medway, Massachussetts.
3. < = not detected at detection limit shown.

GROUNDWATER SERVICES, INC.

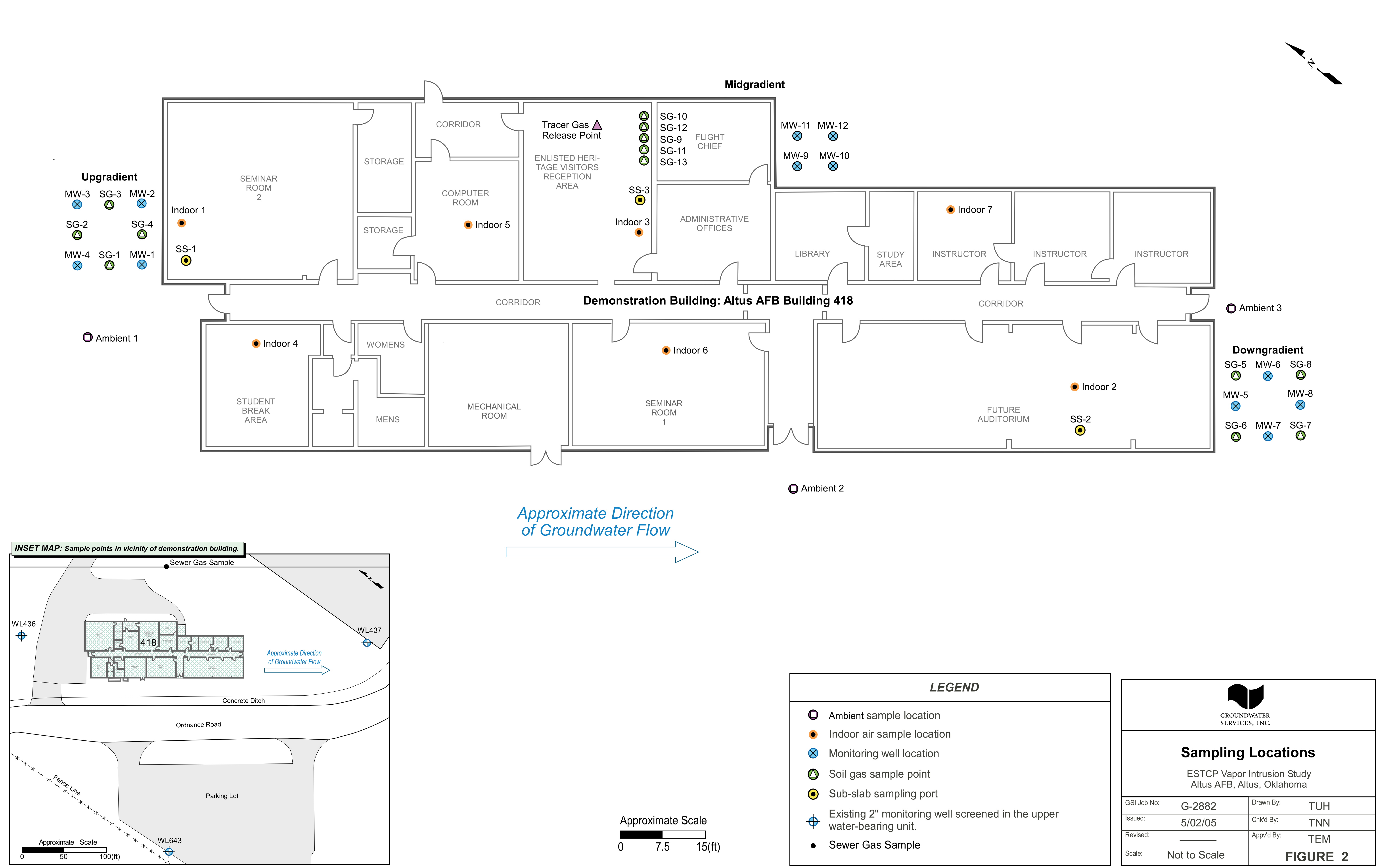
Environmental Security Technology Certification Program
(ESTCP)

RESULTS AND LESSONS LEARNED INTERIM REPORT: ALTUS AFB SITE

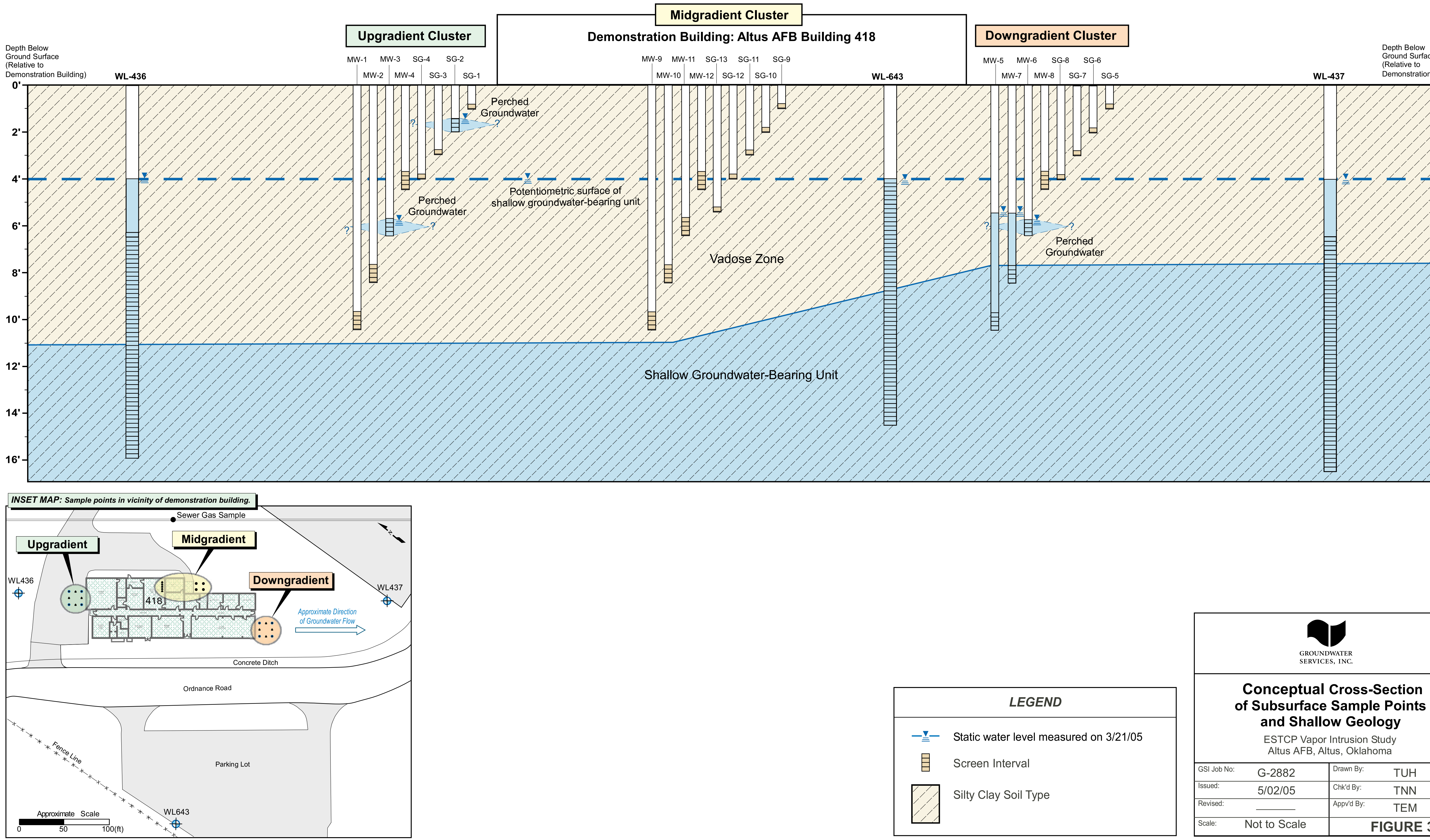
FIGURES



INSET MAP
Kansas
Oklahoma
Altus AFB
Texas
Demonstration Building:
Altus AFB Building 418
TCE plume in shallow
groundwater 2001
Elks Club Golf Course
Winters Property
Pixley Property
Mills Property
TAXIWAY B
TAXIWAY D
ORDNANCE RD
CHALLENGER BLVD
HIGHWAY 62
SOUTHERN UNNAMED TRIBUTARY TO STINKING CREEK
DRAINAGE DITCH
CONCRETE DRAINAGE DITCH
POND
Scale
0 250 500(ft)
N
LEGEND:
EXISTING MONITORING WELL
RFI SOIL BORING
RFI UPPER MONITORING WELL
RFI LOWER MONITORING WELL
RFI DEEP MONITORING WELL
TCE CONCENTRATION SS-17 (ug/L) - UPPER
TCE CONCENTRATION SS-22 (ug/L) - UPPER
ss-17 iso TCE 01 up.dwg
DATE: Sept 26, 2002
QC: D. S. Naleid
SS-17
GROUNDWATER
TCE ISOCONCENTRATION MAP
UPPER WELLS, 2001
ALTUS AIR FORCE BASE
FIG NO 4.5.1-17
GROUNDWATER SERVICES, INC.
Location of Altus AFB
Demonstration Building
ESTCP Vapor Intrusion Study
Altus AFB, Altus, Oklahoma
GSI Job No: G-2882
Drawn By: TUH
Issued: 5/02/05
Chk'd By: TNN
Revised:
Appv'd By: TEM
Scale: As Shown
FIGURE 1



Midgradient
Upgradient
MW-3 SG-3 MW-2
SG-2 SG-4
MW-4 SG-1 MW-1
Indoor 1
SS-1
SEMINAR ROOM 2
STORAGE
STORAGE
CORRIDOR
COMPUTER ROOM
Indoor 5
Tracer Gas Release Point
ENLISTED HERI-TAGE VISITORS RECEPTION AREA
SG-10
SG-12
SG-9
SG-11
SG-13
FLIGHT CHIEF
SS-3
Indoor 3
ADMINISTRATIVE OFFICES
MW-11 MW-12
MW-9 MW-10
LIBRARY
STUDY AREA
Indoor 7
INSTRUCTOR
INSTRUCTOR
INSTRUCTOR
CORRIDOR
Demonstration Building: Altus AFB Building 418
CORRIDOR
Ambient 1
Ambient 3
Indoor 4
STUDENT BREAK AREA
WOMENS
MENS
MECHANICAL ROOM
Indoor 6
SEMINAR ROOM 1
FUTURE AUDITORIUM
Indoor 2
SS-2
Downgradient
SG-5 MW-6 SG-8
MW-5 MW-8
SG-6 MW-7 SG-7
Ambient 2
Approximate Direction of Groundwater Flow
INSET MAP: Sample points in vicinity of demonstration building.
Sewer Gas Sample
WL436
WL437
418
Approximate Direction of Groundwater Flow
Concrete Ditch
Ordnance Road
Parking Lot
Fence Line
WL643
Approximate Scale
0 50 100(ft)
Approximate Scale
0 7.5 15(ft)
LEGEND
Ambient sample location
Indoor air sample location
Monitoring well location
Soil gas sample point
Sub-slab sampling port
Existing 2" monitoring well screened in the upper water-bearing unit.
Sewer Gas Sample
GROUNDWATER SERVICES, INC.
Sampling Locations
ESTCP Vapor Intrusion Study
Altus AFB, Altus, Oklahoma
GSI Job No: G-2882
Issued: 5/02/05
Revised: ______
Scale: Not to Scale
Drawn By: TUH
Chk'd By: TNN
Appv'd By: TEM
FIGURE 2



GROUNDWATER SERVICES, INC.

Conceptual Cross-Section of Subsurface Sample Points and Shallow Geology

ESTCP Vapor Intrusion Study
Altus AFB, Altus, Oklahoma

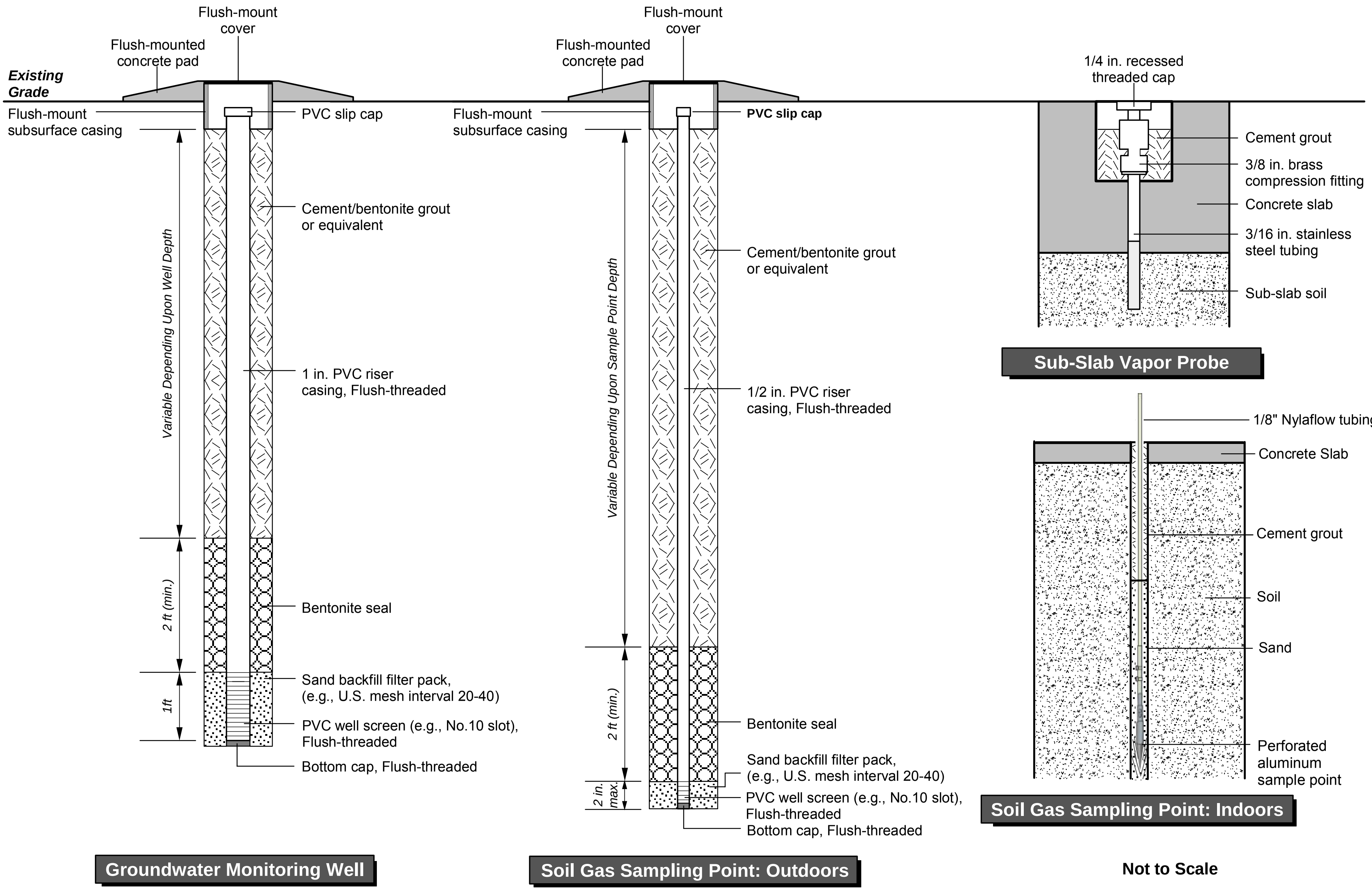
GSI Job No:	G-2882	Drawn By:	TUH
Issued:	5/02/05	Chk'd By:	TNN
Revised:		Appv'd By:	TEM
Scale:	Not to Scale		**FIGURE 3**

GSI Job No.: G-2882
Date Issued: 5/2/05
Page 1 of 1

FIGURE 4

EXAMPLE CONSTRUCTION SPECIFICATIONS FOR ALTUS SITE SAMPLING POINTS

ESTCP Vapor Intrusion Study
Altus AFB, Altus, Oklahoma



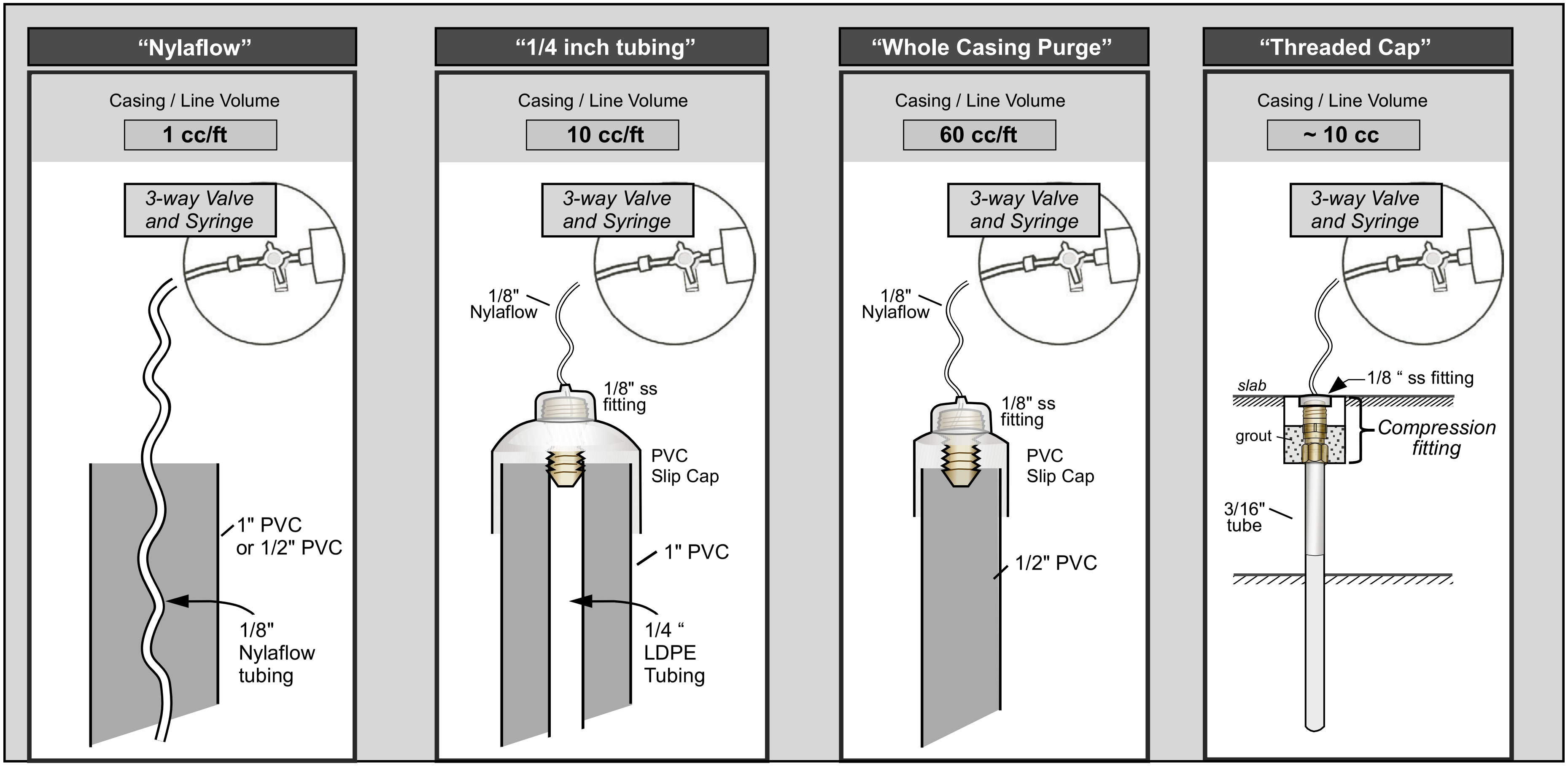
Not to Scale

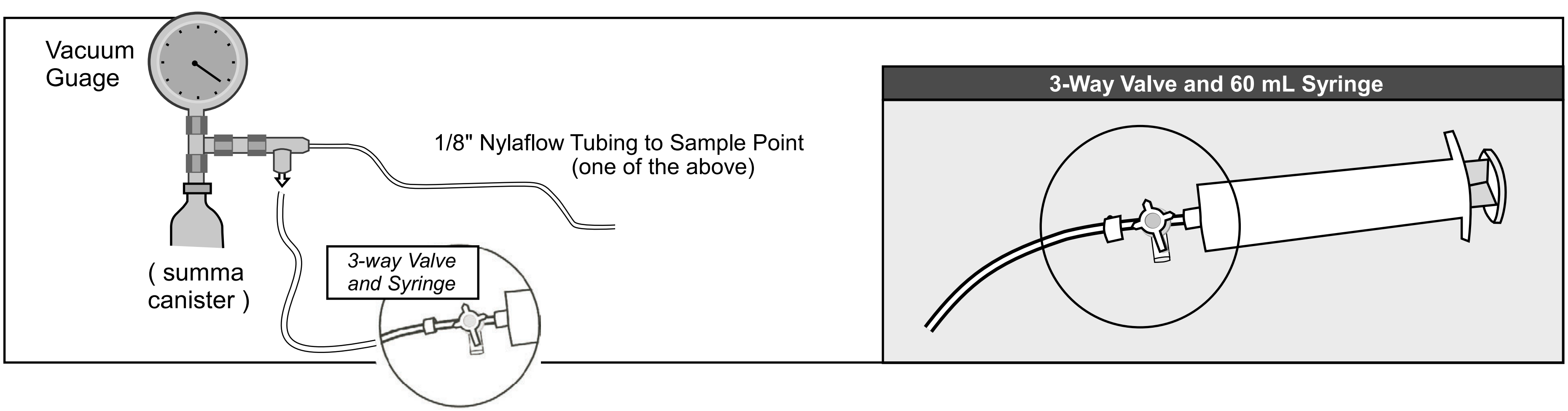
GSI Job No.: G-2882
Date Issued: 5/2/05
Page 1 of 1

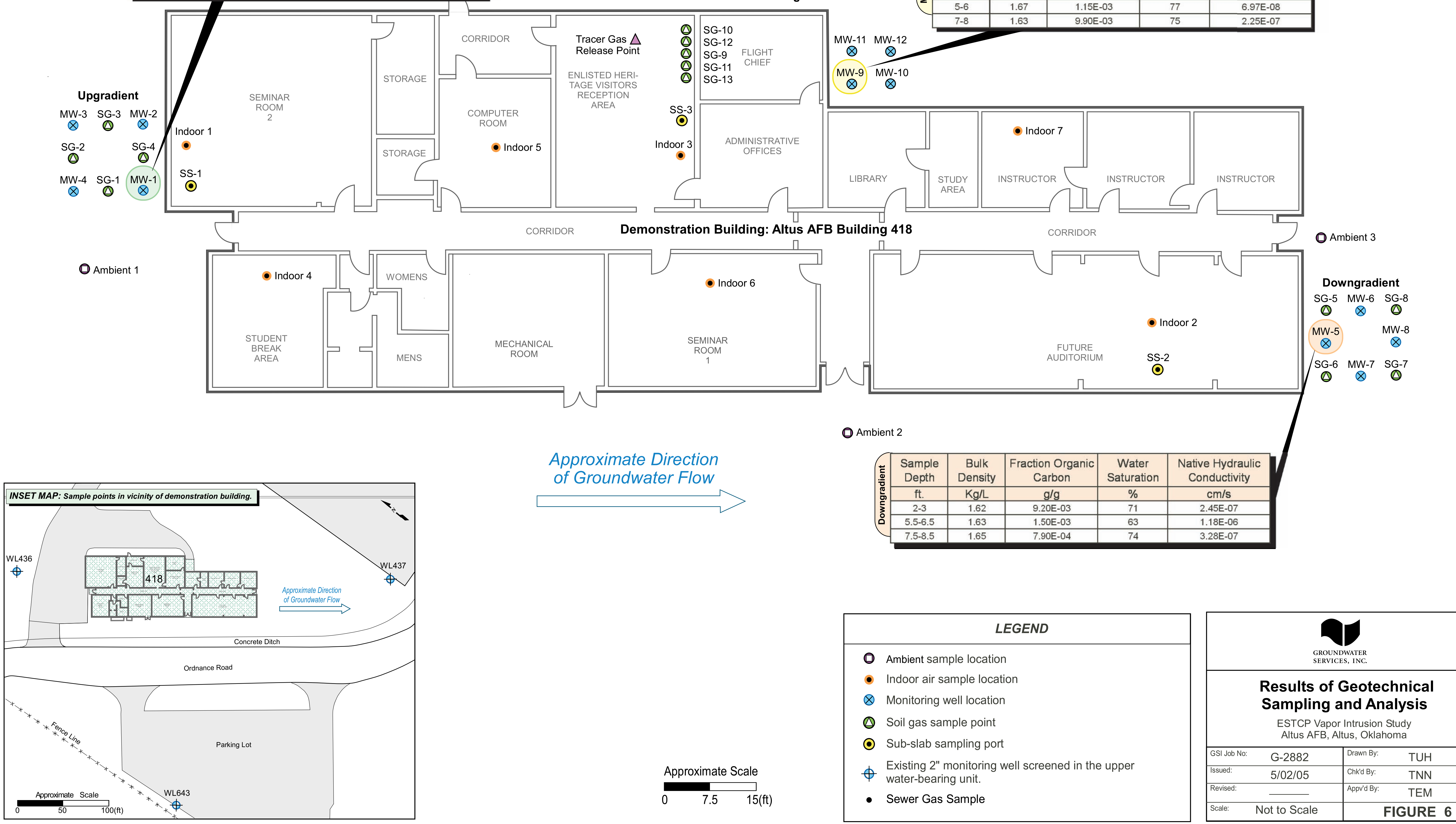
FIGURE 5: SAMPLE COLLECTION METHODS

ESTCP Vapor Intrusion Study
Altus AFB, Altus, Oklahoma

GROUNDWATER SERVICES, INC.







Upgradient

Sample Depth	Bulk Density	Fraction Organic Carbon	Water Saturation	Native Hydraulic Conductivity
ft.	Kg/L	g/g	%	cm/s
1-2	1.49	5.55E-03	69	4.05E-07
4-5	1.72	1.20E-03	74	4.15E-08
7-8	1.6	1.60E-03	65	1.86E-07

Midgradient

Sample Depth	Bulk Density	Fraction Organic Carbon	Water Saturation	Native Hydraulic Conductivity
ft.	Kg/L	g/g	%	cm/s
2-3	1.6	5.05E-03	65	2.76E-07
5-6	1.67	1.15E-03	77	6.97E-08
7-8	1.63	9.90E-03	75	2.25E-07

Downgradient

Sample Depth	Bulk Density	Fraction Organic Carbon	Water Saturation	Native Hydraulic Conductivity
ft.	Kg/L	g/g	%	cm/s
2-3	1.62	9.20E-03	71	2.45E-07
5.5-6.5	1.63	1.50E-03	63	1.18E-06
7.5-8.5	1.65	7.90E-04	74	3.28E-07

LEGEND

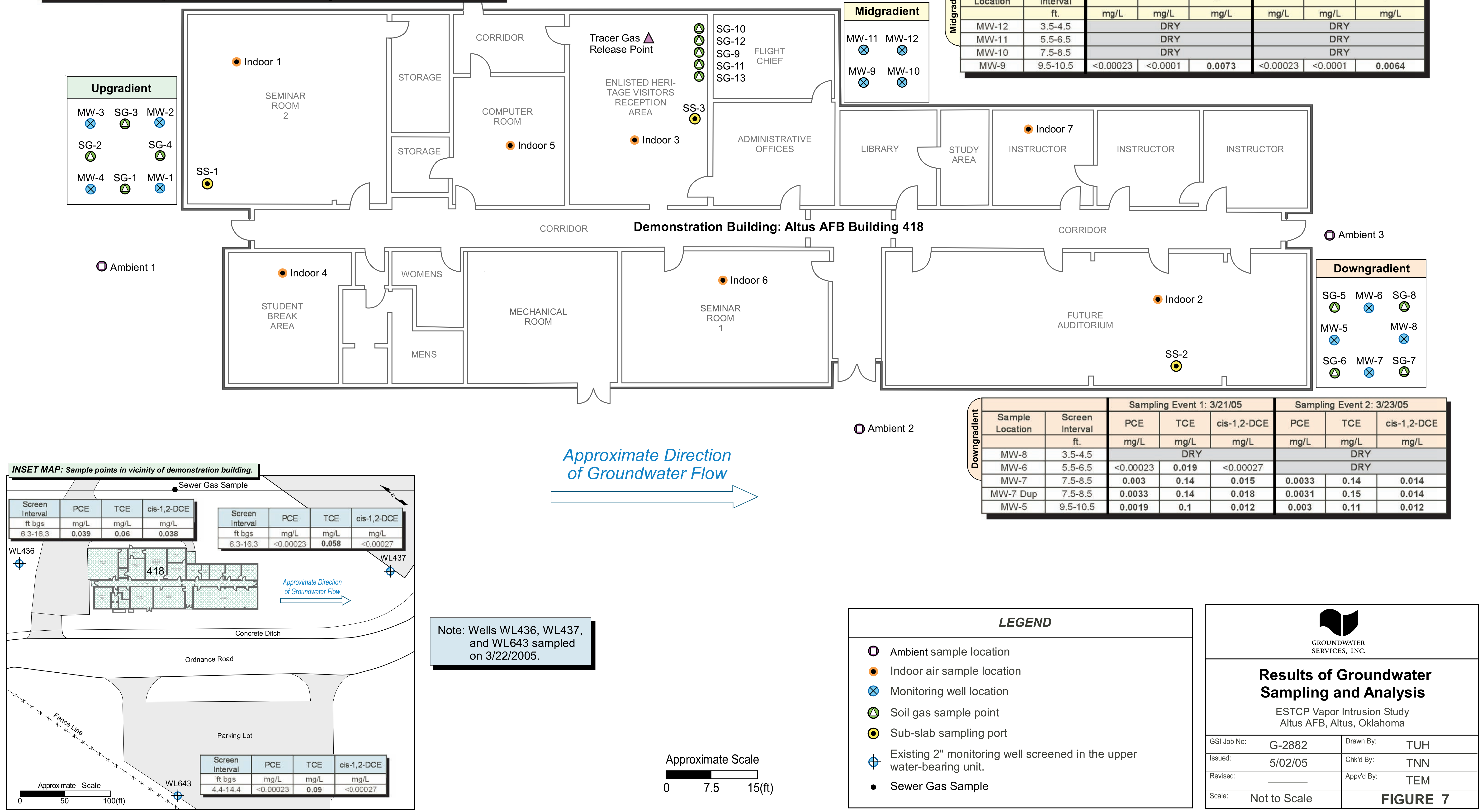
- Ambient sample location
- Indoor air sample location
- Monitoring well location
- Soil gas sample point
- Sub-slab sampling port
- Existing 2" monitoring well screened in the upper water-bearing unit.
- Sewer Gas Sample

GROUNDWATER SERVICES, INC.

Results of Geotechnical Sampling and Analysis

ESTCP Vapor Intrusion Study
Altus AFB, Altus, Oklahoma

GSI Job No: G-2882	Drawn By: TUH
Issued: 5/02/05	Chk'd By: TNN
Revised: ———	Appv'd By: TEM
Scale: Not to Scale	**FIGURE 6**



Upgradient

Sample Location	Screen Interval ft.	Sampling Event 1: 3/21/05 PCE mg/L	TCE mg/L	cis-1,2-DCE mg/L	Sampling Event 2: 3/23/05 PCE mg/L	TCE mg/L	cis-1,2-DCE mg/L
MW-4	3.5-4.5	DRY			DRY		
MW-3	5.5-6.5	<0.00023	**0.022**	<0.00027	DRY		
MW-2	7.5-8.5	DRY			DRY		
MW-1	9.5-10.5	DRY			DRY		

Midgradient

Sample Location	Screen Interval ft.	Sampling Event 1: 3/21/05 PCE mg/L	TCE mg/L	cis-1,2-DCE mg/L	Sampling Event 2: 3/23/05 PCE mg/L	TCE mg/L	cis-1,2-DCE mg/L
MW-12	3.5-4.5	DRY			DRY		
MW-11	5.5-6.5	DRY			DRY		
MW-10	7.5-8.5	DRY			DRY		
MW-9	9.5-10.5	<0.00023	<0.0001	**0.0073**	<0.00023	<0.0001	**0.0064**

Downgradient

Sample Location	Screen Interval ft.	Sampling Event 1: 3/21/05 PCE mg/L	TCE mg/L	cis-1,2-DCE mg/L	Sampling Event 2: 3/23/05 PCE mg/L	TCE mg/L	cis-1,2-DCE mg/L
MW-8	3.5-4.5	DRY			DRY		
MW-6	5.5-6.5	<0.00023	**0.019**	<0.00027	DRY		
MW-7	7.5-8.5	**0.003**	**0.14**	**0.015**	**0.0033**	**0.14**	**0.014**
MW-7 Dup	7.5-8.5	**0.0033**	**0.14**	**0.018**	**0.0031**	**0.15**	**0.014**
MW-5	9.5-10.5	**0.0019**	**0.1**	**0.012**	**0.003**	**0.11**	**0.012**

Inset map: Sewer Gas Sample / WL436

Screen Interval ft bgs	PCE mg/L	TCE mg/L	cis-1,2-DCE mg/L
6.3-16.3	**0.039**	**0.06**	**0.038**

Inset map: WL437

Screen Interval ft bgs	PCE mg/L	TCE mg/L	cis-1,2-DCE mg/L
6.3-16.3	<0.00023	**0.058**	<0.00027

Inset map: WL643

Screen Interval ft bgs	PCE mg/L	TCE mg/L	cis-1,2-DCE mg/L
4.4-14.4	<0.00023	**0.09**	<0.00027

Note: Wells WL436, WL437, and WL643 sampled on 3/22/2005.

LEGEND

- Ambient sample location
- Indoor air sample location
- Monitoring well location
- Soil gas sample point
- Sub-slab sampling port
- Existing 2" monitoring well screened in the upper water-bearing unit.
- Sewer Gas Sample

GROUNDWATER SERVICES, INC.

Results of Groundwater Sampling and Analysis

ESTCP Vapor Intrusion Study
Altus AFB, Altus, Oklahoma

GSI Job No:	G-2882	Drawn By:	TUH
Issued:	5/02/05	Chk'd By:	TNN
Revised:		Appv'd By:	TEM
Scale:	Not to Scale		FIGURE 7

Table 1

Sample Location	Depth / Location	Sampling Event 1: 3/22/05 PCE	TCE	cis-1,2-DCE	Sampling Event 2: 3/23-24/05 PCE	TCE	cis-1,2-DCE
	ft.	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Ambient 1	Ambient	<5	<5	<5	<5	<5	<5
Indoor 1	Indoor	<5	<5	<5	7	<5	<5
SS-1	Sub-Slab	130	39	<5	140	49	<5
SG-1	1	7	<5	<5	<5	<5	<5
SG-2	2		WATER			WATER	
SG-3	3	<5	<5	<5	<5	<5	<5
SG-4	4	<5	<5	<5	<5	<5	<5
SG-4 Dup	4	<5	<5	<5	NA	NA	NA
MW-4	3.5-4.5	NA	NA	NA	10	8	<5
MW-3	5.5-6.5	12	56	<5	40	180	<5
MW-2	7.5-8.5	NA	NA	NA	130	450	46
MW-1	9.5-10.5	NA	NA	NA	450	390	71

Table 2

Sample Location	Depth / Location	Sampling Event 1: 3/22/05 PCE	TCE	cis-1,2-DCE	Sampling Event 2: 3/23-24/05 PCE	TCE	cis-1,2-DCE
	ft.	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Ambient 2	Ambient	<5	<5	<5	<5	<5	<5
Indoor 3	Indoor	<5	<5	<5	<5	<5	<5
SS-3	Sub-Slab	22	8	<5	18	7	<5
SS-3 Dup	Sub-Slab	NA	NA	NA	16	6	<5
SG-9	1	23	5	<5	22	<5	<5
SG-10	2	27	<5	<5	24	<5	<5
SG-11	3	54	14	<5	49	13	<5
SG-12	4	95	6	<5	56	8	<5
MW-10	7.5-8.5	NA	NA	NA	20	130	130
MW-9	9.5-10.5	<5	15	270	<5	7	100

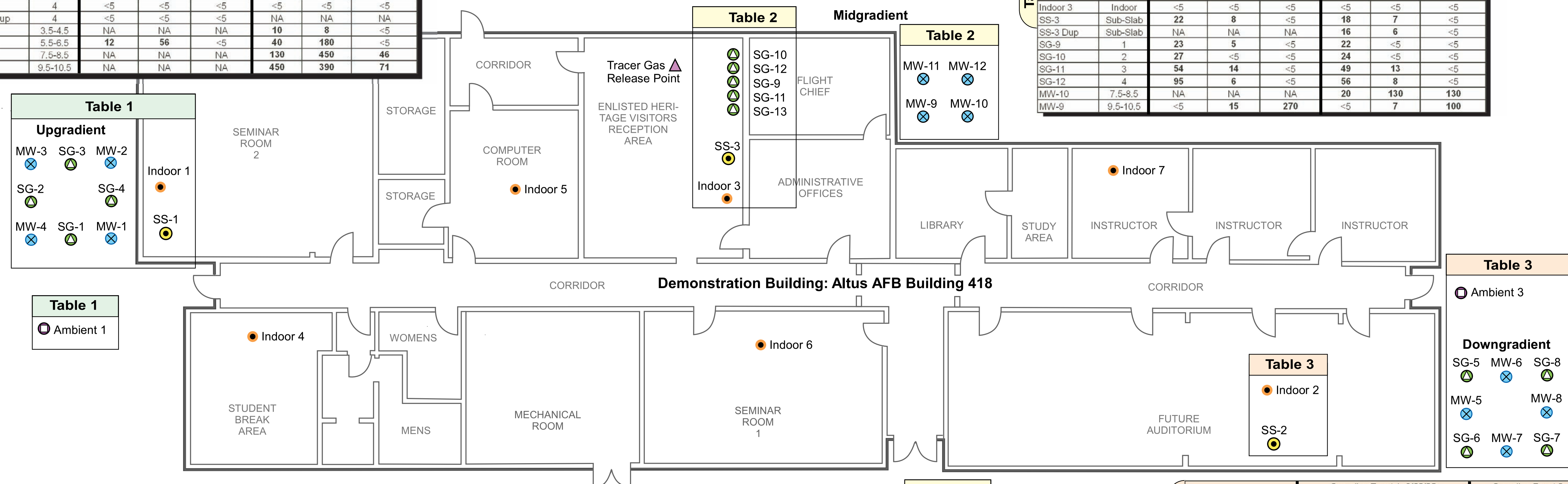
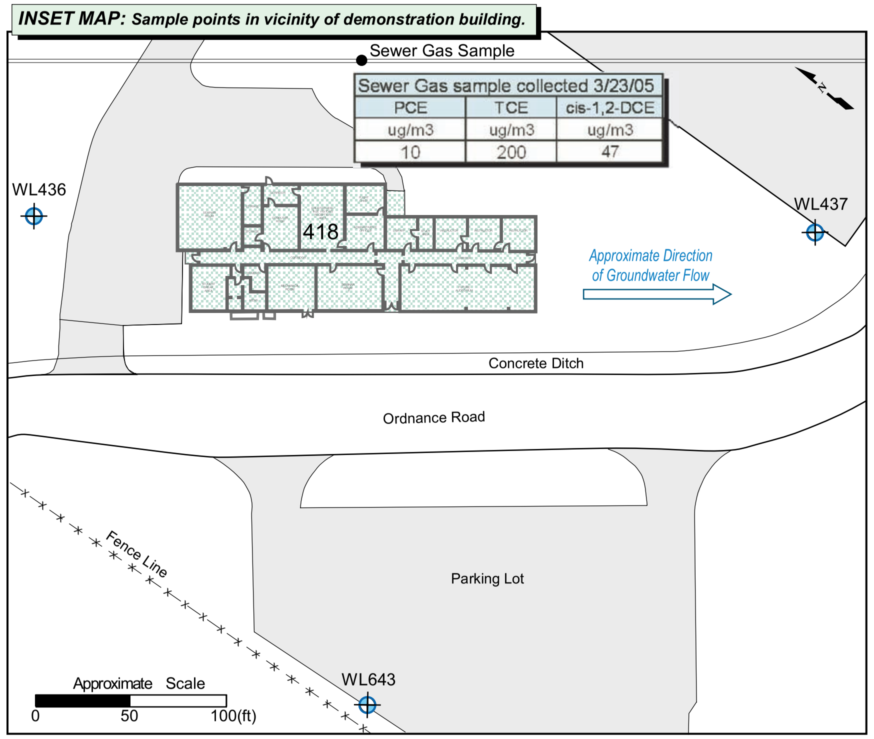


Table 3

Sample Location	Depth / Location	Sampling Event 1: 3/22/05 PCE	TCE	cis-1,2-DCE	Sampling Event 2: 3/23-24/05 PCE	TCE	cis-1,2-DCE
	ft.	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Ambient 3	Ambient	<5	<5	<5	<5	<5	<5
Indoor 2	Indoor	<5	<5	<5	<5	<5	<5
SS-2	Sub-Slab	16	8	<5	18	9	<5
SS-2 Dup	Sub-Slab	31	12	<5	NA	NA	NA
SG-5	1	16	<5	<5	7	<5	<5
SG-6	2	13	<5	<5	7	<5	<5
SG-7	3	10	<5	<5	<5	<5	<5
SG-8	4	9	<5	<5	7	<5	<5
SG-8 Dup	4	NA	NA	NA	6	6	<5
MW-8	3.5-4.5	NA	NA	NA	10	<5	<5
MW-6	5.5-6.5	<5	57	<5	7	43	<5
MW-7	7.5-8.5	NA	NA	NA	5	380	170
MW-5	9.5-10.5	NA	NA	NA	<5	480	180

Approximate Direction of Groundwater Flow

INSET MAP: *Sample points in vicinity of demonstration building.*



Sewer Gas sample collected 3/23/05		
PCE	TCE	cis-1,2-DCE
ug/m3	ug/m3	ug/m3
10	200	47

Approximate Scale

0 7.5 15(ft)

LEGEND

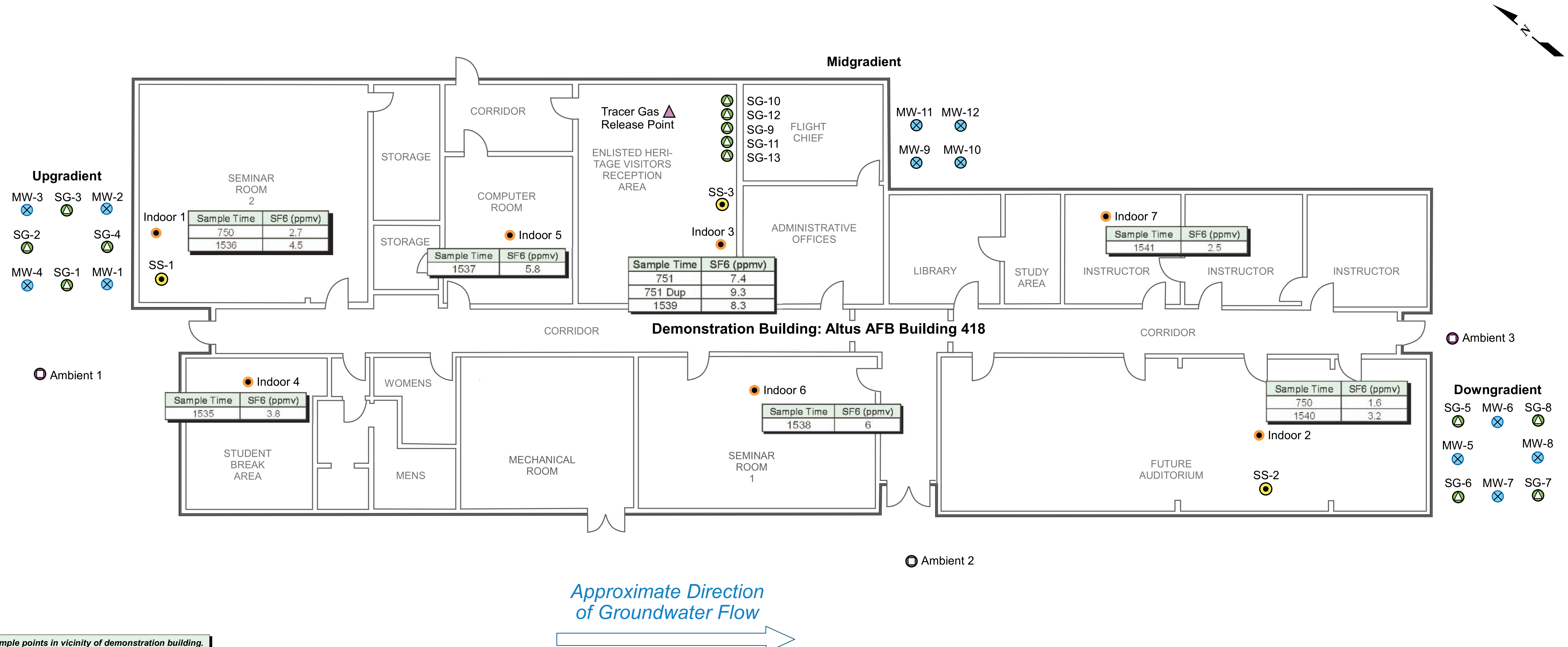
- Ambient sample location
- Indoor air sample location
- Monitoring well location
- Soil gas sample point
- Sub-slab sampling port
- Existing 2" monitoring well screened in the upper water-bearing unit.
- Sewer Gas Sample

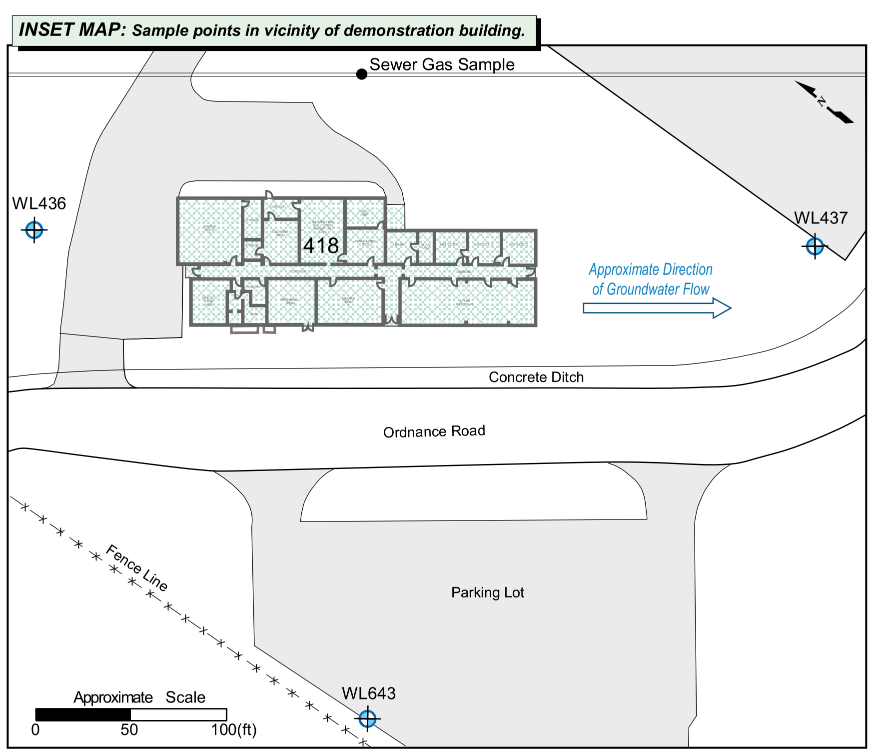
GROUNDWATER SERVICES, INC.

Gas Sampling and Analysis Results (Ambient, Indoor, Sub-Slab, Soil Gas, Well Headspace)

ESTCP Vapor Intrusion Study
Altus AFB, Altus, Oklahoma

GSI Job No:	G-2882	Drawn By:	TUH
Issued:	5/02/05	Chk'd By:	TNN
Revised:	______	Appv'd By:	TEM
Scale:	Not to Scale	**FIGURE 8**	





Approximate Scale
0 7.5 15(ft)

Note: Sample date = March 23, 2005

LEGEND

- Ambient sample location
- Indoor air sample location
- Monitoring well location
- Soil gas sample point
- Sub-slab sampling port
- Existing 2" monitoring well screened in the upper water-bearing unit.
- Sewer Gas Sample

GROUNDWATER SERVICES, INC.

Results of SF_6 Tracer Gas Sampling and Analysis

ESTCP Vapor Intrusion Study
Altus AFB, Altus, Oklahoma

GSI Job No:	G-2882	Drawn By:	TUH
Issued:	5/02/05	Chk'd By:	TNN
Revised:	———	Appv'd By:	TEM
Scale:	Not to Scale		**FIGURE 9**

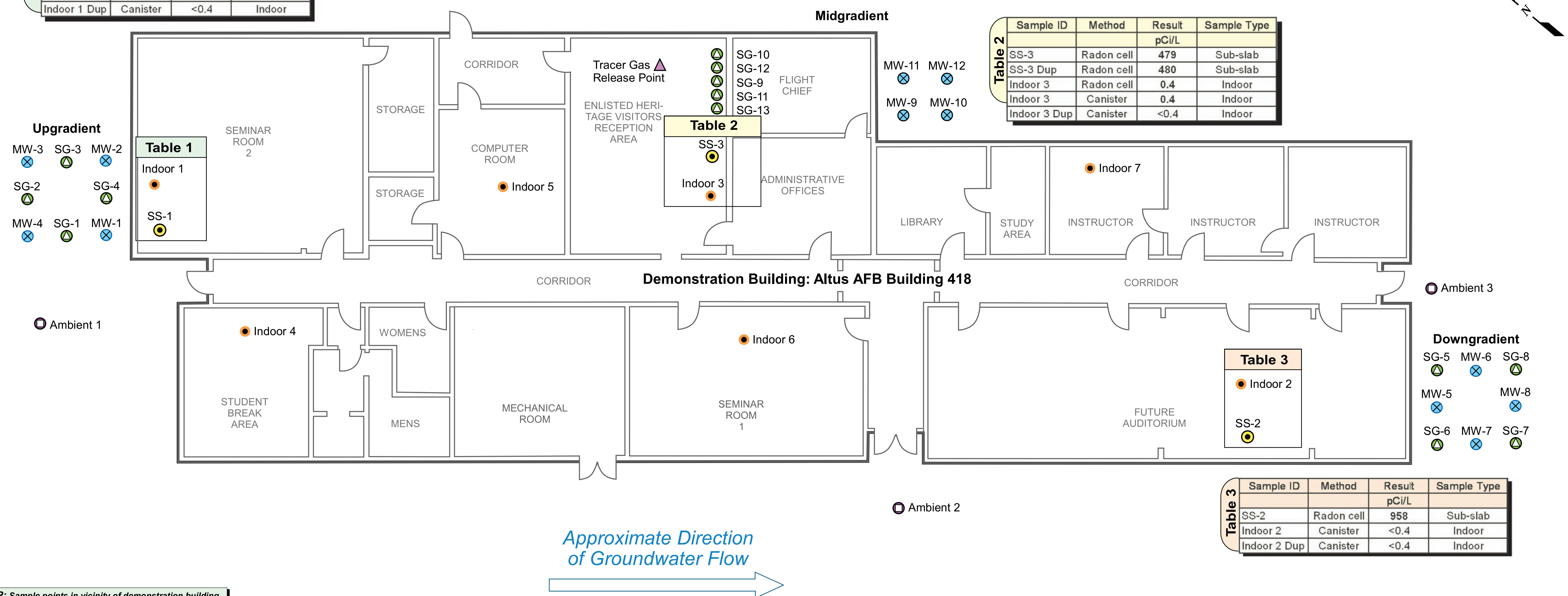


Table 1

Sample ID	Method	Result pCi/L	Sample Type
SS-1	Radon cell	1092	Sub-slab
Indoor 1	Canister	<0.4	Indoor
Indoor 1 Dup	Canister	<0.4	Indoor

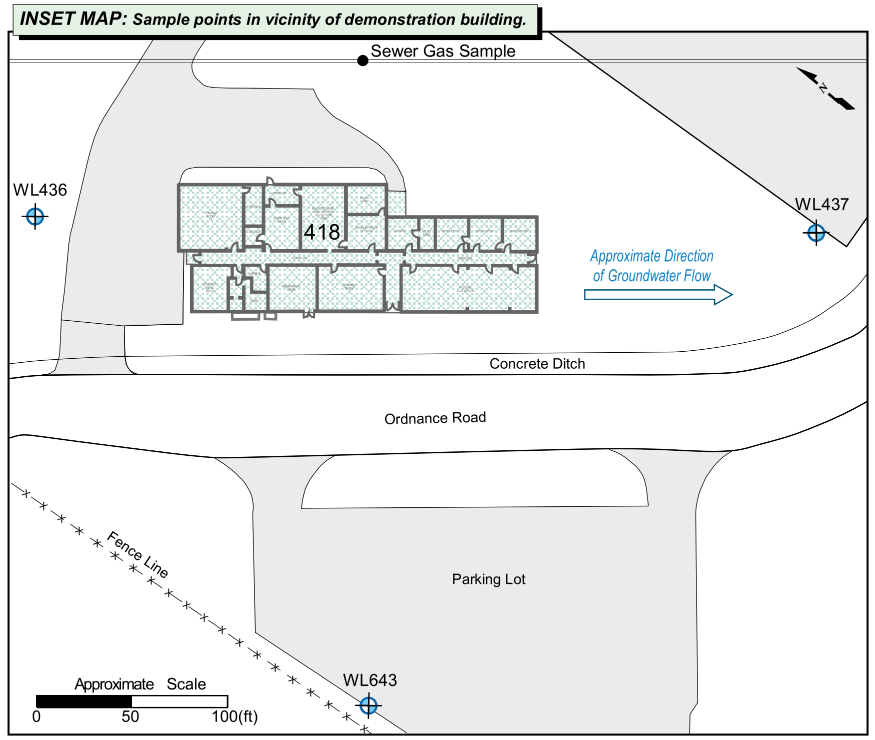
Table 2

Sample ID	Method	Result pCi/L	Sample Type
SS-3	Radon cell	479	Sub-slab
SS-3 Dup	Radon cell	480	Sub-slab
Indoor 3	Radon cell	0.4	Indoor
Indoor 3	Canister	0.4	Indoor
Indoor 3 Dup	Canister	<0.4	Indoor

Table 3

Sample ID	Method	Result pCi/L	Sample Type
SS-2	Radon cell	958	Sub-slab
Indoor 2	Canister	<0.4	Indoor
Indoor 2 Dup	Canister	<0.4	Indoor

INSET MAP: *Sample points in vicinity of demonstration building.*



LEGEND

- Ambient sample location
- Indoor air sample location
- Monitoring well location
- Soil gas sample point
- Sub-slab sampling port
- Existing 2" monitoring well screened in the upper water-bearing unit.
- Sewer Gas Sample

GROUNDWATER SERVICES, INC.

Results of Radon Sampling and Analysis

ESTCP Vapor Intrusion Study
Altus AFB, Altus, Oklahoma

GSI Job No:	G-2882	Drawn By:	TUH
Issued:	5/02/05	Chk'd By:	TNN
Revised:	———	Appv'd By:	TEM
Scale:	Not to Scale		FIGURE 10

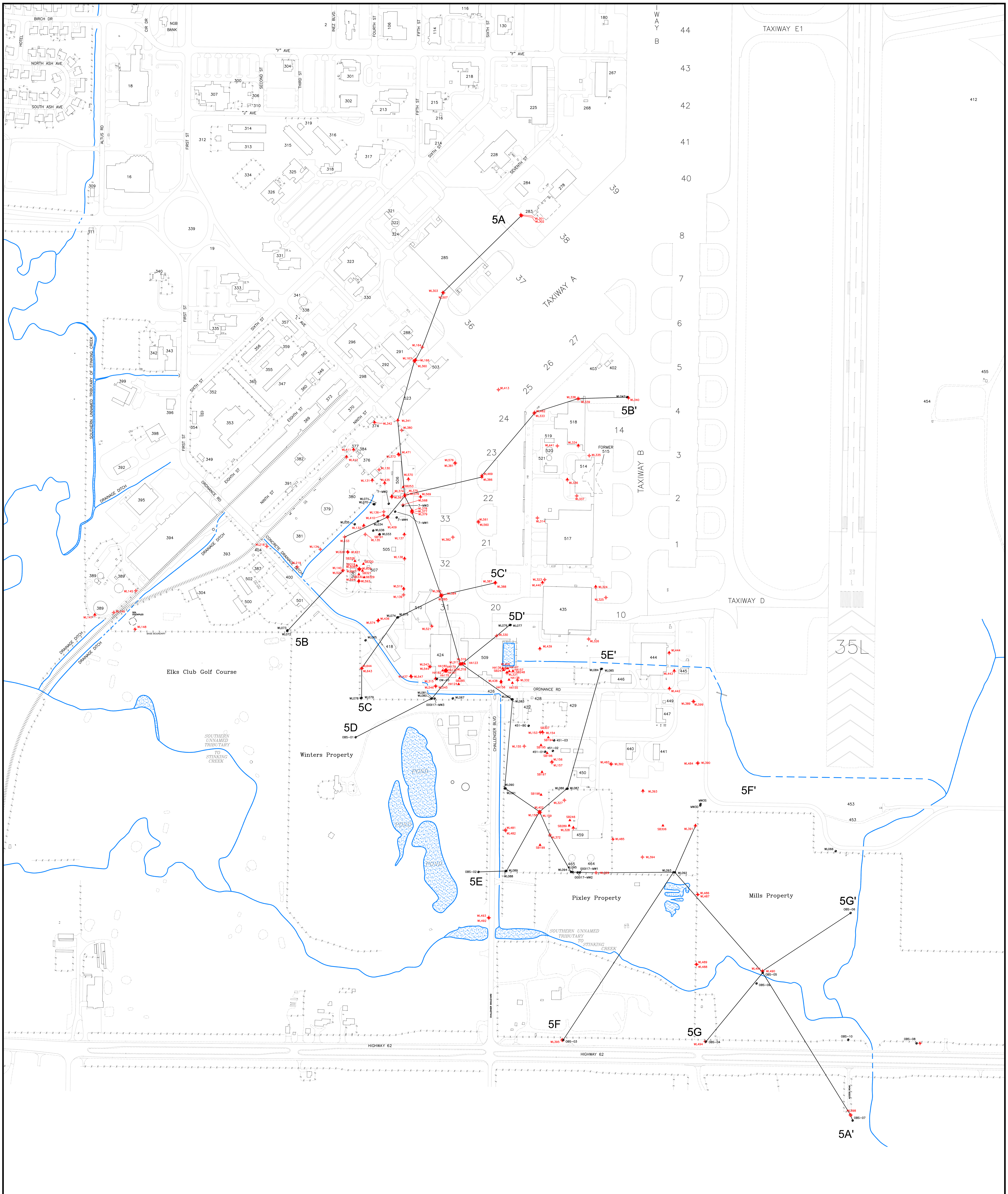
GROUNDWATER SERVICES, INC.

Environmental Security Technology Certification Program
(ESTCP)

RESULTS AND LESSONS LEARNED INTERIM REPORT: ALTUS AFB SITE

Attachment A

Site Figures from the Altus AFB RFI Report



NEED TO FIND TW-07 AND TW-10

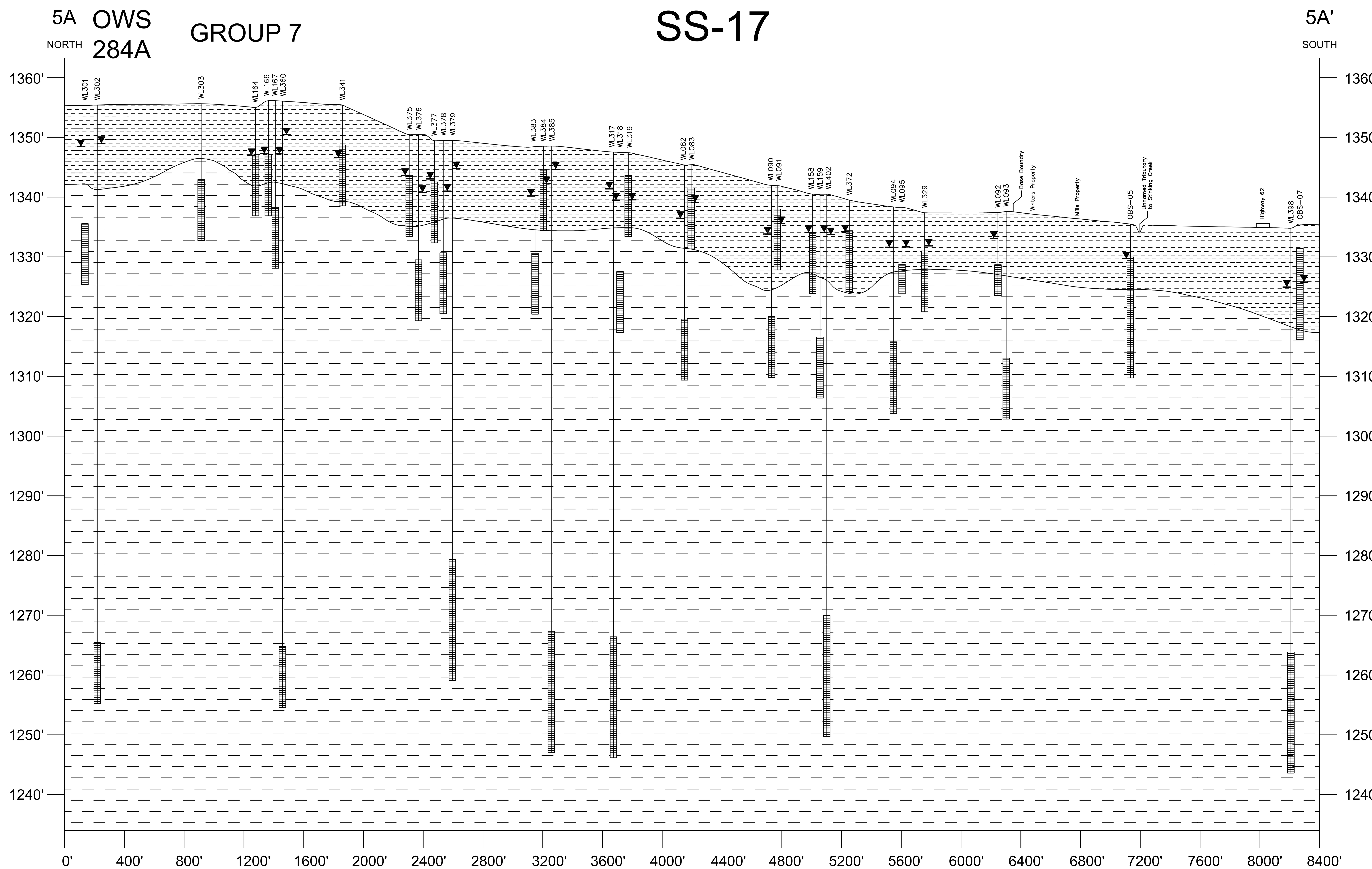
SCALE: 1" = 200'

LEGEND:

- EXISTING MONITORING WELL
- RFI SOIL BORING
- RFI UPPER MONITORING WELL
- RFI LOWER MONITORING WELL
- RFI DEEP MONITORING WELL

ss-17 sitemap.dwg

DATE: Oct 14, 2002	SS-17 CROSS-SECTION LOCATION MAP	FIG NO: 4.5.1-2
QC: D. S. Naleid	ALTUS AIR FORCE BASE	



LEGEND:

CLAY

RED WEATHERED SHALE

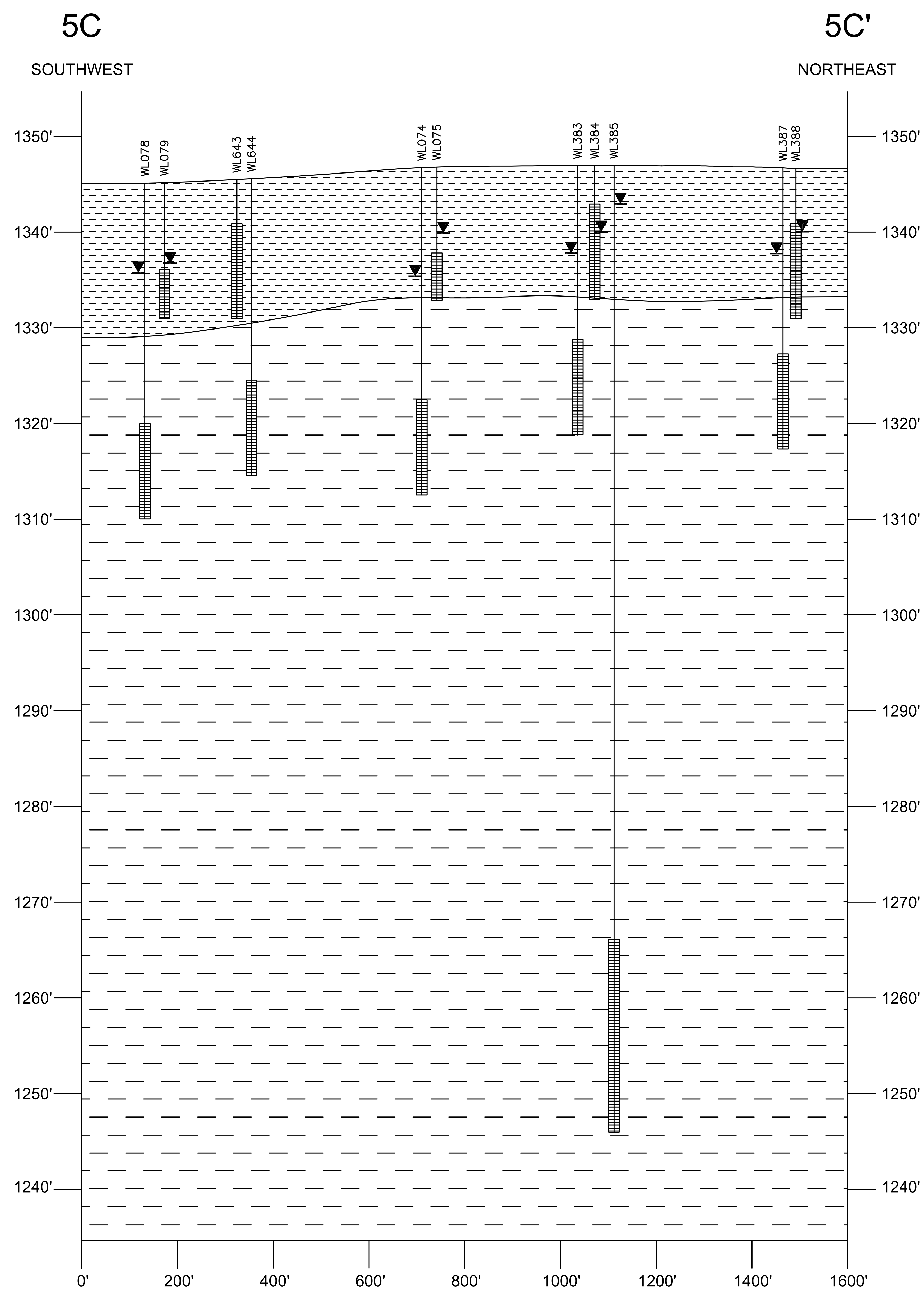
WATER TABLE (MAY 2001)

SCREENED INTERVAL

SCALE:
HORIZONTAL: 1" = 400'
VERTICAL: 1" = 10'
VERTICAL EXAGGERATION: 40X

DATE: Oct 14, 2002	SS-17 GEOLOGIC CROSS-SECTION 5A - 5A'	FIG NO: 4.5.1-3
QC: D. S. Naleid	ALTUS AIR FORCE BASE	

ss-17 cross 5A.dwg



LEGEND:

CLAY

RED WEATHERED SHALE

WATER TABLE (MAY 2001)

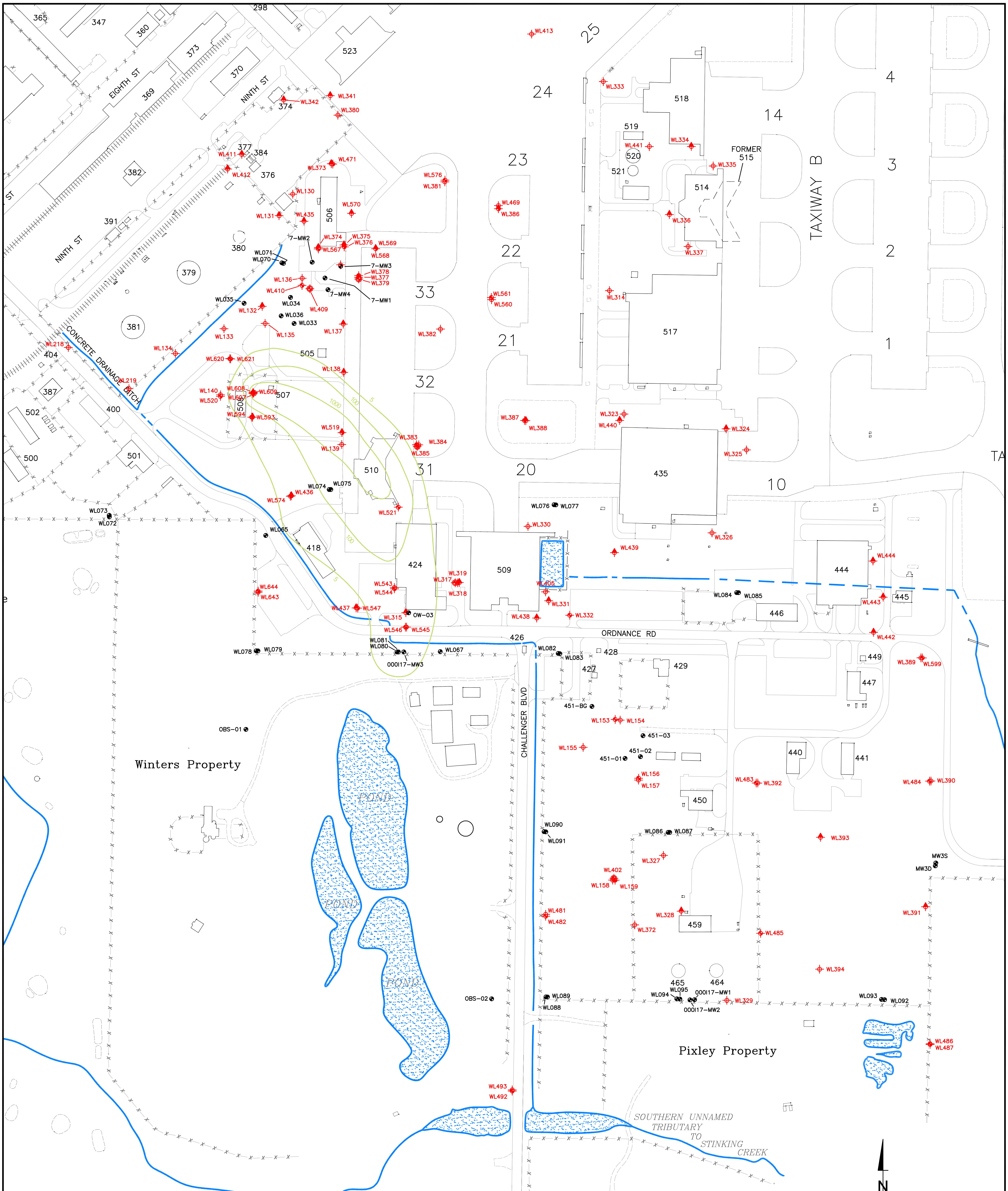
SCREENED INTERVAL

ss-17 cross 5C.dwg

SCALE:
HORIZONTAL: 1" = 200'
VERTICAL: 1" = 10'
VERTICAL EXAGGERATION: 20X

DATE: Oct 10, 2002	SS-17 GEOLOGIC CROSS-SECTION 5C - 5C' ALTUS AIR FORCE BASE	FIG NO: 4.5.1-5
QC: D. S. Naleid		

DATE: Sept 26, 2002	SS-17 GROUNDWATER TCE ISOCONCENTRATION MAP UPPER WELLS, 2001 ALTUS AIR FORCE BASE	FIG NO: 4.5.1-17
QC: D. S. Naleid		



LEGEND:
- EXISTING MONITORING WELL
- RFI SOIL BORING
- RFI UPPER MONITORING WELL
- RFI LOWER MONITORING WELL
- RFI DEEP MONITORING WELL
- PCE CONCENTRATION (ug/L) - UPPER

ss-17 iso PCE 01 up.dwg

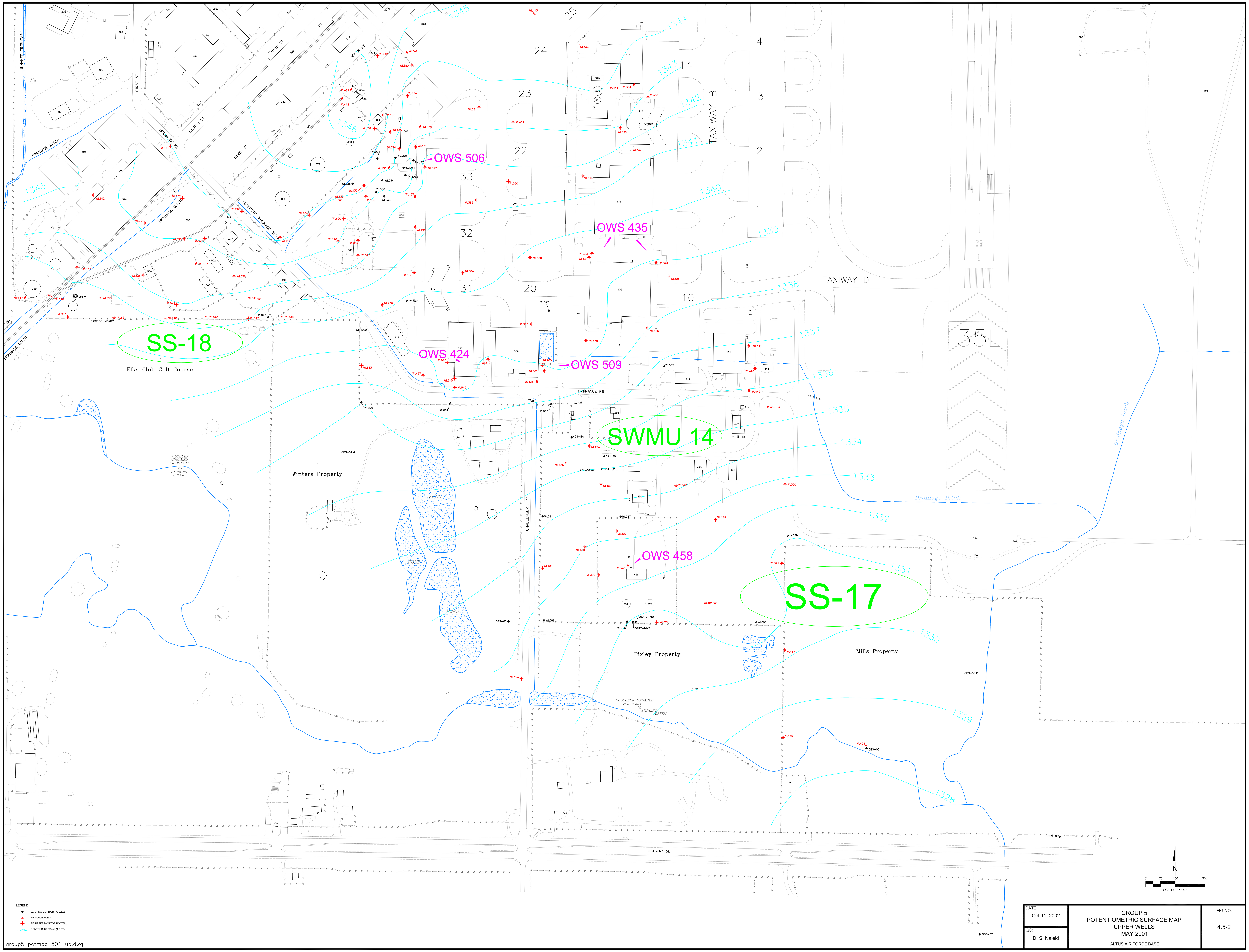
DATE: Sept 24, 2002	SS-17 GROUNDWATER PCE ISOCONCENTRATION MAP UPPER WELLS	FIG NO: 4.5.1-22
QC: D. S. Naleid	ALTUS AIR FORCE BASE	

LEGEND:

- EXISTING MONITORING WELL
- RFI SOIL BORING
- RFI UPPER MONITORING WELL
- RFI LOWER MONITORING WELL
- RFI DEEP MONITORING WELL
- DCE CONCENTRATION (ug/L) - UPPER

ss-17 iso DCE 01 up.dwg

DATE: Sept 26, 2002	SS-17 GROUNDWATER DCE ISOCONCENTRATION MAP UPPER WELLS ALTUS AIR FORCE BASE	FIG NO: 4.5.1-20
QC: D. S. Naleid		


OWS 506
OWS 435
OWS 424
OWS 509
OWS 458
SS-18
SWMU 14
SS-17
Elks Club Golf Course
Winters Property
Pixley Property
Mills Property
TAXIWAY B
TAXIWAY D
35L
HIGHWAY 62
CHALLENGER BLVD
ORDNANCE RD
FIRST ST
EIGHTH ST
NINTH ST
DRAINAGE DITCH
CONCRETE DRAINAGE DITCH
UNNAMED TRIBUTARY
SOUTHERN UNNAMED TRIBUTARY TO STINKING CREEK
POND
Drainage Ditch
BASE BOUNDARY
1346
1345
1344
1343
1342
1341
1340
1339
1338
1337
1336
1335
1334
1333
1332
1331
1330
1329
1328
LEGEND:
EXISTING MONITORING WELL
RFI SOIL BORING
RFI UPPER MONITORING WELL
CONTOUR INTERVAL (1.0 FT)
group5 potmap 501 up.dwg
SCALE: 1" = 150'
DATE: Oct 11, 2002
QC: D. S. Naleid
GROUP 5
POTENTIOMETRIC SURFACE MAP
UPPER WELLS
MAY 2001
ALTUS AIR FORCE BASE
FIG NO: 4.5-2

GROUNDWATER SERVICES, INC.

Environmental Security Technology Certification Program
(ESTCP)

RESULTS AND LESSONS LEARNED INTERIM REPORT: ALTUS AFB SITE

Attachment B

Geological Logs and Static Water Levels

GROUNDWATER SERVICES, INC.

TABLE B.1
STATIC WATER LEVEL MEASUREMENTS
ESTCP Vapor Intrusion Study
Altus Air Force Base
Altus, Oklahoma

Well No.	Installed Total Depth ft, bgs	3/21/2005 Depth to Water ft, bgs	3/23/2005 Depth to Water ft, bgs
MW-1	10.5	DRY	10.30
MW-2	8.5	DRY	DRY
MW-3	6.5	6.40	DRY
MW-4	4.5	DRY	DRY
MW-5	10.5	5.70	6.20
MW-6	6.5	6.20	6.30
MW-7	8.5	5.70	6.10
MW-8	4.5	DRY	DRY
MW-9	10.5	9.50	10.00
MW-10	8.5	DRY	DRY
MW-11	6.5	DRY	DRY
MW-12	4.5	DRY	DRY
WL-436	16.3	6.55	nm
WL-437	16.3	5.30	nm
WL-643	14.4	5.40	nm

NOTES:
1) Monitoring well locations shown on Figure 1.
2) Wells WL-436,437, and 643 were measured on 3/2
3) bgs = below ground surface
nm = not measured

MAJOR DIVISIONS			GRAPHIC SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVEL (LITTLE OR NO FINES)		GW	Well-graded gravels, gravel-sand mixtures, little or no fines
				GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	Silty gravels, gravel-sand-silt mixtures
				GC	Clayey gravels, gravel-sand-clay mixtures
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	CLEAN SAND (LITTLE OR NO FINES)		SW	Well-graded sands, gravelly sands, little or no fines
				SP	Poorly-graded sands, gravelly sands, little or no fines
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	Silty sands, sand-silt mixtures
				SC	Clayey sands, sand-clay mixtures
FINE GRAINED SOILS MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50%		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity
				CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
				OL	Organic silts and organic silty clays of low plasticity
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50%		MH	Inorganic silts, micaceous or diatomaceous fine sand or silty soils
				CH	Inorganic clays or high plasticity, fat clays
				OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS				PT	Peat, humus, swamp soils with high organic contents

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

KEY TO SYMBOLS

SHELBY TUBE SAMPLE

DIRECT PUSH SAMPLE

SPLIT-SPOON SAMPLE

NO RECOVERY

CONTINUOUS CORE BARREL SAMPLE

STATIC WATER LEVEL

GROUNDWATER SERVICES, INC.

UNIFIED SOIL CLASSIFICATION SYSTEM

GSI Job No.	G-2882	Drawn By:	SMP	**FIGURE B.1**
Issued:	05/02/05	Apr'd By:	SMP	

GEOLOGIST: Tim Nickels
DRILLER: Alpine Field Services, Inc. (Jeff Steerman)
DRILLING METHOD: Direct Push / Geoprobe
HOLE DIAMETER: 2 inch

COMPLETION DATE: March 15, 2005
GROUND SURFACE ELEV.: NA Ft., MSL
TOP OF CASING ELEV: NA Ft., MSL
PLANT COORDINATES: N NA, W NA

DEPTH IN FEET	GEOTECH SAMPLE	BLOWS/FT	OVA (ppm)	USCS SYMBOL	SOIL DESCRIPTION
					GROUND SURFACE
0					Dark brown silty CLAY (CL)
					-brownish-red, soft and moist from 4.5 to 8 ft
5					
					-red from 8 to 11 ft
10					-dry and crumbly from 10 to 11 ft
					Total Depth = 11.0 Ft.
15					
20					
25					
30					
35					

GROUNDWATER SERVICES, INC.

LOG OF SOIL BORING
Up Gradient Area

Building 418 Altus Air Force Base
Altus, Oklahoma

GSI Job No. G-2882
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Issued: 05/02/05

FIGURE B.2

GEOLOGIST: Tim Nickels
DRILLER: Alpine Field Services, Inc. (Jeff Steerman)
DRILLING METHOD: Direct Push / Geoprobe
HOLE DIAMETER: 2 inch

COMPLETION DATE: March 15, 2005
GROUND SURFACE ELEV.: NA Ft., MSL
TOP OF CASING ELEV: NA Ft., MSL
PLANT COORDINATES: N NA, W NA

DEPTH IN FEET	GEOTECH SAMPLE	BLOWS/FT	OVA (ppm)	USCS SYMBOL	SOIL DESCRIPTION GROUND SURFACE
0					Dark brown silty CLAY (CL)
5					-red below 5.5 ft
					-moist from 7 ft to 9.5 ft
10					-saturated silt pocket with diesel odor at 10.5 ft
					Total Depth = 10.5 Ft.
15					
20					
25					
30					
35					

GROUNDWATER SERVICES, INC.

LOG OF SOIL BORING
Mid Gradient Area

Building 418 Altus Air Force Base
Altus, Oklahoma

GSI Job No. G-2882
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FIGURE B.3

GEOLOGIST: Tim Nickels
DRILLER: Alpine Field Services, Inc. (Jeff Steerman)
DRILLING METHOD: Direct Push / Geoprobe
HOLE DIAMETER: 2 inch

COMPLETION DATE: March 15, 2005
GROUND SURFACE ELEV.: NA Ft., MSL
TOP OF CASING ELEV: NA Ft., MSL
PLANT COORDINATES: N NA, W NA

DEPTH IN FEET	GEOTECH SAMPLE	BLOWS/FT	OVA (ppm)	USCS SYMBOL	SOIL DESCRIPTION
					GROUND SURFACE
0				CL	Dark brown silty CLAY (CL)
5					-red with occasional calcareous nodules below 4 ft
					-moist below 6.5 ft
					-soft below 7 ft
				ML	Red clayey SILT (ML)
10					-saturated below 10 ft with coarse sand present from 10.5 to 10.75 ft
					Total Depth = 11.5 Ft.
15					
20					
25					
30					
35					

GROUNDWATER SERVICES, INC.

LOG OF SOIL BORING

Down Gradient Area

Building 418 Altus Air Force Base
Altus, Oklahoma

GSI Job No. G-2882
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FIGURE B.4

GROUNDWATER SERVICES, INC.

Environmental Security Technology Certification Program
(ESTCP)

RESULTS AND LESSONS LEARNED INTERIM REPORT: ALTUS AFB SITE

Attachment C

Results of Groundwater Analyses

TABLE C.1
RESULTS OF GROUNDWATER ANALYSES
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

SAMPLE LOCATION:	MW-9	MW-9	WL-436	WL-437	WL-643	SG-2	SG-2	Trip Blank	Field Blank
SCREEN INTERVAL (ft):	9.5-10.5	9.5-10.5	6.3-16.3	6.3-16.3	4.4-14.4	1.9-2	1.9-2	NA	NA
SAMPLE TYPE:	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
SAMPLE DATE:	3/21/2005	3/23/2005	3/22/2005	3/22/2005	3/22/2005	3/23/2005	3/24/2005	3/22/2005	3/21/2005
COMPOUND	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Compounds of Interest									
Benzene	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	< 0.00010	< 0.00010
Bromodichloromethane	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	< 0.00016	< 0.00016
Bromoform	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021	< 0.00021	< 0.00021
Bromomethane	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	< 0.00060	< 0.00060
Carbon Tetrachloride	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021	< 0.00021	< 0.00021
Chlorobenzene	<0.00011	<0.00011	<0.00011	<0.00011	<0.00011	<0.00011	<0.00011	< 0.00011	< 0.00011
Chloroethane	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021	< 0.00021	< 0.00021
Chloroform	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	< 0.00016	< 0.00016
Chloromethane	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	< 0.00015	< 0.00015
Dibromochloromethane	<0.00018	<0.00018	<0.00018	<0.00018	<0.00018	<0.00018	<0.00018	< 0.00018	< 0.00018
1,1-Dichloroethane	<0.00014	<0.00014	<0.00014	<0.00014	<0.00014	<0.00014	<0.00014	< 0.00014	< 0.00014
1,2-Dichloroethane	<0.00025	<0.00025	<0.00025	<0.00025	<0.00025	<0.00025	<0.00025	< 0.00025	< 0.00025
1,1-Dichloroethene	<0.00017	<0.00017	<0.00017	<0.00017	<0.00017	<0.00017	<0.00017	< 0.00017	< 0.00017
cis-1,2-Dichloroethene	**0.0073**	**0.0064**	**0.038**	<0.00027	<0.00027	<0.00027	<0.00027	< 0.00027	< 0.00027
trans-1,2-Dichloroethene	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	< 0.00015	< 0.00015
1,2-Dichloropropane	<0.00022	<0.00022	<0.00022	<0.00022	<0.00022	<0.00022	<0.00022	< 0.00022	< 0.00022
Ethylbenzene	<0.00013	<0.00013	<0.00013	<0.00013	<0.00013	<0.00013	<0.00013	< 0.00013	< 0.00013
Methylene Chloride	<0.00032	<0.00032	<0.00032	<0.00032	<0.00032	<0.00032	<0.00032	< 0.00032	< 0.00032
Styrene	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	< 0.00016	< 0.00016
1,1,2,2-Tetrachloroethane	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	< 0.00020	< 0.00020
Tetrachloroethene	<0.00023	<0.00023	**0.039**	<0.00023	<0.00023	<0.00023	<0.00023	< 0.00023	< 0.00023
Toluene	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	**0.0028**	<0.00016	< 0.00016	< 0.00016
1,1,1-Trichloroethane	<0.00035	<0.00035	<0.00035	<0.00035	<0.00035	<0.00035	<0.00035	< 0.00035	< 0.00035
1,1,2-Trichloroethane	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	< 0.00020	< 0.00020
Trichloroethene	<0.0001	<0.0001	**0.060**	**0.0058**	**0.0090**	<0.0001	<0.0001	< 0.00010	< 0.00010
Vinyl Chloride	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	< 0.00020	< 0.00020
Xylenes (total)	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	< 0.00042	< 0.00042
Acetone	**0.0088**	**0.0043**	<0.00053	<0.00053	<0.00053	**0.0074**	**0.0025**	< 0.00053	**0.0029**
Carbon Disulfide	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	< 0.00010	< 0.00010
cis-1,3-Dichloropropene	<0.00012	<0.00012	<0.00012	<0.00012	<0.00012	<0.00012	<0.00012	< 0.00012	< 0.00012
trans-1,3-Dichloropropene	<0.00011	<0.00011	<0.00011	<0.00011	<0.00011	<0.00011	<0.00011	< 0.00011	< 0.00011
Methyl Ethyl Ketone (2-Butanone)	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	< 0.00015	< 0.00015
2-Hexanone	<0.00037	<0.00037	<0.00037	<0.00037	<0.00037	<0.00037	<0.00037	< 0.00037	< 0.00037
4-Methyl-2-pentanone (MIBK)	<0.00041	<0.00041	<0.00041	<0.00041	<0.00041	<0.00041	<0.00041	< 0.00041	< 0.00041
1,2-Dichloroethene (total)	**0.0073**	**0.0064**	**0.038**	<0.00028	<0.00028	<0.00028	<0.00028	< 0.00028	< 0.00028

NOTES:
1. All groundwater samples were analyzed by Severn Trent Laboratories, Inc., Houston, Texas Method 8260B.
2. Screen intervals indicated for WL-436, and WL-437 are estimated based on knowledge of other wells in the area.
3. Detected analytes are presented in **bold** type.
4. < = not detected at detection limit shown.

TABLE C.1
RESULTS OF GROUNDWATER ANALYSES
ESTCP: Vapor Intrusion Study

Altus Air Force Base, Altus, Oklahoma

						DUPLICATE		*DUPLICATE*
SAMPLE LOCATION:	MW-3	MW-5	MW-5	MW-6	MW-7	MW-7	MW-7	MW-7
SCREEN INTERVAL (ft BGS):	5.5-6.5	9.5-10.5	9.5-10.5	5.5-6.5	7.5-8.5	7.5-8.5	7.5-8.5	7.5-8.5
SAMPLE TYPE:	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
SAMPLE DATE:	3/21/2005	3/21/2005	3/23/2005	3/21/2005	3/21/2005	3/21/2005	3/23/2005	3/23/2005
COMPOUND	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Compounds of Interest								
Benzene	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Bromodichloromethane	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016
Bromoform	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021
Bromomethane	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006	<0.0006
Carbon Tetrachloride	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021
Chlorobenzene	<0.00011	<0.00011	<0.00011	<0.00011	<0.00011	<0.00011	<0.00011	<0.00011
Chloroethane	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021	<0.00021
Chloroform	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016
Chloromethane	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015
Dibromochloromethane	<0.00018	<0.00018	<0.00018	<0.00018	<0.00018	<0.00018	<0.00018	<0.00018
1,1-Dichloroethane	<0.00014	<0.00014	<0.00014	<0.00014	<0.00014	<0.00014	<0.00014	<0.00014
1,2-Dichloroethane	<0.00025	<0.00025	<0.00025	<0.00025	<0.00025	<0.00025	<0.00025	<0.00025
1,1-Dichloroethene	<0.00017	<0.00017	<0.00017	<0.00017	<0.00017	<0.00017	<0.00017	<0.00017
cis-1,2-Dichloroethene	<0.00027	**0.012**	**0.012**	<0.00027	**0.015**	**0.018**	**0.014**	**0.014**
trans-1,2-Dichloroethene	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	**0.0010**	<0.00015	<0.00015
1,2-Dichloropropane	<0.00022	<0.00022	<0.00022	<0.00022	<0.00022	<0.00022	<0.00022	<0.00022
Ethylbenzene	<0.00013	<0.00013	<0.00013	<0.00013	<0.00013	<0.00013	<0.00013	<0.00013
Methylene Chloride	<0.00032	<0.00032	<0.00032	<0.00032	<0.00032	<0.00032	<0.00032	<0.00032
Styrene	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016
1,1,2,2-Tetrachloroethane	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Tetrachloroethene	<0.00023	**0.0019**	**0.0030**	<0.00023	**0.0030**	**0.0033**	**0.0033**	**0.0031**
Toluene	**0.0042**	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016	<0.00016
1,1,1-Trichloroethane	<0.00035	<0.00035	<0.00035	<0.00035	<0.00035	<0.00035	<0.00035	<0.00035
1,1,2-Trichloroethane	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Trichloroethene	**0.0022**	**0.10**	**0.11**	**0.0019**	**0.14**	**0.14**	**0.14**	**0.15**
Vinyl Chloride	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002
Xylenes (total)	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042	<0.00042
Acetone	**0.011**	**0.036**	**0.0064**	**0.025**	**0.010**	**0.011**	**0.0042**	**0.0034**
Carbon Disulfide	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
cis-1,3-Dichloropropene	<0.00012	<0.00012	<0.00012	<0.00012	<0.00012	<0.00012	<0.00012	<0.00012
trans-1,3-Dichloropropene	<0.00011	<0.00011	<0.00011	<0.00011	<0.00011	<0.00011	<0.00011	<0.00011
Methyl Ethyl Ketone (2-Butanone)	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015	<0.00015
2-Hexanone	<0.00037	<0.00037	<0.00037	<0.00037	<0.00037	<0.00037	<0.00037	<0.00037
4-Methyl-2-pentanone (MIBK)	<0.00041	<0.00041	<0.00041	<0.00041	<0.00041	<0.00041	<0.00041	<0.00041
1,2-Dichloroethene (total)	<0.00028	**0.012**	**0.012**	<0.00028	**0.015**	**0.019**	**0.014**	**0.014**

NOTES:
1. All groundwater samples were analyzed by Severn Trent Laboratories, Inc., Houston, Texas Method 8260B.
2. Screen intervals indicated for WL-436, and WL-437 are estimated based on knowledge of other wells in the area.
3. Detected analytes are presented in **bold** type.
4. < = not detected at detection limit shown.

GROUNDWATER SERVICES, INC.

Environmental Security Technology Certification Program
(ESTCP)

RESULTS AND LESSONS LEARNED INTERIM REPORT: ALTUS AFB SITE

Attachment D

Results of Rejected Gas Analyses: TO-15

Table D.1	Results of Sub Slab, Ambient, and Indoor Analyses: TO-15
Table D.2	Results of Soil Gas Analyses: TO-15

TABLE D.1
RESULTS OF SUB SLAB, AMBIENT, AND INDOOR ANALYSES: TO-15
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

SAMPLE LOCATION:	Sub-slab 1	Sub-slab 2	Sub-slab 3	Sub-slab 2	Sub-slab 3	Indoor 1	Indoor 2	Indoor 3	Indoor 3	Ambient	Ambient 3
CASING DEPTH (ft bgs):	0.7	0.7	0.7	0.7	0.7	NA	NA	NA	NA	NA	NA
SAMPLE DATE:	3/22/2005	3/22/2005	3/22/2005	3/23/2005	3/23/2005	3/22/2005	3/22/2005	3/22/2005	3/23/2005	3/22/2005	3/23/2005
COMPOUND	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Compounds of Interest											
Propene	**2**	< 2	**2**	**4**	**5**	< 2	**3**	< 2	**2**	**21**	**3**
Dichlorodifluoromethane	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Chloromethane	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	**2**	< 2	< 2
Dichlorotetrafluoroethane	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7
Vinyl chloride	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
1,3-Butadiene	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Bromomethane	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Chloroethane	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
Bromoethane	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Trichlorofluoromethane	**20**	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6
Acetone	**28**	**47**	**26**	**62**	**88**	**81**	**218**	**20**	**55**	**3794**	**90**
1,1-Dichloroethene	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
1,1,2-Trichlorotrifluoroethane	**620**	**45**	**21**	**41**	**25**	**11**	**11**	**11**	**12**	**11**	**11**
Allyl chloride	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
Methylene chloride	< 3	< 3	**4**	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
Carbon disulfide	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
trans-1,2-Dichloroethene	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Methyl tert-butyl ether	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Vinyl acetate	**5**	**14**	< 4	**4**	< 4	< 4	**63**	< 4	**4**	**1230**	< 4
1,1-Dichloroethane	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	**6**	< 4
2-Butanone	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
n-Hexane	< 4	< 4	< 4	< 4	< 4	< 4	**10**	< 4	< 4	**123**	< 4
cis-1,2-Dichloroethene	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Ethyl acetate	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	**36**	< 4
Chloroform	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Tetrahydrofuran	< 3	< 3	< 3	< 3	**144**	< 3	< 3	< 3	< 3	< 3	< 3
1,1,1-Trichloroethane	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
1,2-Dichloroethane	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	**4**	< 4
Benzene	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	**13**	< 3
Carbon tetrachloride	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6
Cyclohexane	< 3	**5**	< 3	< 3	< 3	< 3	**19**	< 3	< 3	**186**	**4**
2,2,4-Trimethylpentane	**12**	**44**	**22**	< 5	< 5	< 5	**224**	**5**	< 5	**2004**	< 5
n-Heptane	< 4	< 4	< 4	< 4	< 4	< 4	**6**	< 4	< 4	**35**	< 4
Trichloroethene	**113**	**17**	**38**	**17**	**21**	**11**	< 5	**7**	**8**	< 5	< 5
1,2-Dichloropropane	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
1,4-Dioxane	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Bromodichloromethane	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7
cis-1,3-Dichloropropene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
4-Methyl-2-pentanone	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
trans-1,3-Dichloropropene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Toluene	**5**	**5**	**5**	**6**	**8**	**4**	**6**	**5**	**9**	**12**	**7**
1,1,2-Trichloroethane	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
2-Hexanone	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Dibromochloromethane	< 9	< 9	< 9	< 9	< 9	< 9	< 9	< 9	< 9	< 9	< 9
Tetrachloroethene	**460**	**68**	**59**	**54**	**81**	< 7	**1218**	**18**	**15**	**12**	**9**
1,2-Dibromoethane (EDB)	< 8	< 8	< 8	< 8	< 8	< 8	< 8	< 8	< 8	< 8	< 8
Chlorobenzene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Ethylbenzene	**5**	**8**	**14**	**5**	**4**	< 4	**38**	< 4	< 4	**40**	**82**
m,p-Xylene	**5**	**4**	**6**	**6**	**5**	< 4	**10**	< 4	**5**	**10**	**14**
Styrene	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
o-Xylene	< 4	< 4	**5**	**5**	< 4	< 4	**8**	< 4	**4**	**8**	**29**
Bromoform	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
1,1,2,2-Tetrachloroethane	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7
4-Ethyltoluene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
1,3,5-Trimethylbenzene	< 5	**6**	**7**	< 5	< 5	< 5	**14**	< 5	< 5	**9**	**6**
1,2,4-Trimethylbenzene	**11**	**13**	**21**	**17**	**24**	**7**	**46**	**8**	**21**	**20**	**1815**
1,3-Dichlorobenzene	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	**7**
Benzyl chloride	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
1,4-Dichlorobenzene	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	**7**	< 6	**7**
1,2-Dichlorobenzene	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6
1,2,4-Trichlorobenzene	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7
Hexachlorbutadiene	< 11	< 11	< 11	< 11	< 11	< 11	< 11	< 11	< 11	< 11	< 11

NOTES:
1. Samples were analyzed by H&P Mobile Geochemistry, Solana Beach, California by Method TO-15.
2. Detected analytes are presented in bold type.
3. < = not detected at detection limit shown.

TABLE D.2
RESULTS OF SOIL GAS ANALYSES: TO-15
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

						DUPLICATE				
SAMPLE LOCATION:	SG-1	SG-1	SG-3	SG-3	SG-4	SG-4	SG-4	SG-5	SG-5	SG-6
SCREEN DEPTH (ft bgs):	1	1	3	3	4	4	4	1	1	2
SAMPLE DATE:	3/22/2005	3/24/2005	3/22/2005	3/24/2005	3/22/2005	3/22/2005	3/24/2005	3/22/2005	3/24/2005	3/22/2005
SAMPLE COLLECTION METHOD:	Slip Cap	Slip Cap	Slip Cap	Slip Cap	Slip Cap	Slip Cap	Slip Cap	Slip Cap	Slip Cap	Slip Cap
COMPOUND	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Compounds of Interest										
Propene	< 2	**91**	**241**	**31**	**430**	**46**	**481**	< 2	**95**	< 2
Dichlorodifluoromethane	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	**84**
Chloromethane	**2**	**10**	< 2	< 2	< 2	< 2	**2**	< 2	**3**	< 2
Dichlorotetrafluoroethane	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Vinyl chloride	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
1,3-Butadiene	< 2	< 2	< 2	< 2	< 2	< 2	**8**	< 2	< 2	< 2
Bromomethane	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Chloroethane	< 3	< 3	< 3	< 3	< 3	< 3	< 3	**34**	< 3	< 3
Bromoethane	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Trichlorofluoromethane	< 6	< 6	< 6	< 6	< 6	< 6	**7**	< 6	< 6	< 6
Acetone	< 2	**64**	**147**	**92**	**147**	**57**	**216**	< 2	**9249**	**232**
1,1-Dichloroethene	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
1,1,2-Trichlorotrifluoroethane	< 8	**14**	**44**	**16**	**26**	**15**	**34**	< 8	**13**	**12**
Allyl chloride	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
Methylene chloride	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
Carbon disulfide	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
trans-1,2-Dichloroethene	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Methyl tert-butyl ether	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Vinyl acetate	< 4	< 4	**13**	**7**	**7**	< 4	**8**	< 4	< 4	**6**
1,1-Dichloroethane	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
2-Butanone	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
n-Hexane	< 4	< 4	**9**	**7**	**4**	< 4	**6**	< 4	< 4	**5**
cis-1,2-Dichloroethene	< 4	< 4	< 4	< 4	< 4	< 4	**4**	< 4	< 4	< 4
Ethyl acetate	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Chloroform	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	**5**	< 5
Tetrahydrofuran	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
1,1,1-Trichloroethane	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
1,2-Dichloroethane	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Benzene	< 3	< 3	**4**	**4**	< 3	< 3	**5**	< 3	**4**	< 3
Carbon tetrachloride	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6
Cyclohexane	< 3	< 3	**52**	**16**	**16**	**4**	**19**	**5**	< 3	< 3
2,2,4-Trimethylpentane	< 5	**6**	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
n-Heptane	**7**	< 4	**102**	**27**	**16**	< 4	**16**	**5**	< 4	**11**
Trichloroethene	**42**	< 5	**30**	5	5	**10**	**70**	**25**	< 5	**172**
1,2-Dichloropropane	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
1,4-Dioxane	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Bromodichloromethane	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7
cis-1,3-Dichloropropene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
4-Methyl-2-pentanone	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
trans-1,3-Dichloropropene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Toluene	**13**	**14**	**45**	**33**	**23**	**8**	**53**	**34**	**37**	**45**
1,1,2-Trichloroethane	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
2-Hexanone	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Dibromochloromethane	< 9	< 9	< 9	< 9	< 9	< 9	< 9	< 9	< 9	< 9
Tetrachloroethene	**40**	**14**	**42**	< 7	< 7	**13**	**108**	**43**	**22**	**68**
1,2-Dibromoethane (EDB)	< 8	< 8	< 8	< 8	< 8	< 8	< 8	< 8	< 8	< 8
Chlorobenzene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Ethylbenzene	< 4	**5**	< 4	**6**	< 4	< 4	**4**	**6**	**11**	< 4
m,p-Xylene	< 4	**7**	< 4	**7**	**5**	< 4	**7**	**10**	**8**	**7**
Styrene	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
o-Xylene	< 4	**5**	< 4	**6**	< 4	< 4	**6**	**477**	**160**	**607**
Bromoform	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
1,1,2,2-Tetrachloroethane	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7
4-Ethyltoluene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
1,3,5-Trimethylbenzene	**10**	**5**	< 5	**5**	< 5	< 5	< 5	**3827**	**589**	**883**
1,2,4-Trimethylbenzene	**17**	**43**	**9**	**93**	**18**	**7**	**11**	**1030**	**34**	**13**
1,3-Dichlorobenzene	**20**	< 6	< 6	**7**	< 6	< 6	< 6	< 6	< 6	< 6
Benzyl chloride	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
1,4-Dichlorobenzene	**20**	< 6	< 6	**7**	< 6	< 6	< 6	< 6	< 6	< 6
1,2-Dichlorobenzene	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6
1,2,4-Trichlorobenzene	< 7	< 7	**15**	< 7	**12**	**10**	< 7	< 7	< 7	**13**
Hexachlorbutadiene	< 11	< 11	< 11	< 11	< 11	< 11	< 11	< 11	< 11	< 11

NOTES:
1. Samples were analyzed by H&P Mobile Geochemistry, Solana Beach, California by Method TO-15.
2. Detected analytes are presented in bold type.
3. < = not detected at detection limit shown.

TABLE D.2
RESULTS OF SOIL GAS ANALYSES: TO-15
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

SAMPLE LOCATION:	SG-6	SG-7	SG-7	SG-8	SG-8	*DUPLICATE* SG-8	SG-9	SG-10	SG-11	SG-12
SCREEN DEPTH (ft bgs):	2	3	3	4	4	4	1	2	3	4
SAMPLE DATE:	3/24/2005	3/22/2005	3/24/2005	3/22/2005	3/24/2005	3/24/2005	3/22/2005	3/22/2005	3/22/2005	3/22/2005
SAMPLE COLLECTION METHOD:	Slip Cap	Slip Cap	Slip Cap	Slip Cap	Slip Cap	Slip Cap	Slip Cap	Slip Cap	Slip Cap	Slip Cap
COMPOUND	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3	ug/m3
Compounds of Interest										
Propene	**258**	**378**	**1100**	**55**	**1083**	**567**	**3**	**3**	**3**	**70**
Dichlorodifluoromethane	< 5	< 5	< 5	**6**	< 5	< 5	< 5	< 5	< 5	< 5
Chloromethane	**2**	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Dichlorotetrafluoroethane	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Vinyl chloride	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
1,3-Butadiene	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2	< 2
Bromomethane	< 4	**6**	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Chloromethane	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
Bromoethane	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Trichlorofluoromethane	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6
Acetone	**949**	**81**	**308**	**57**	**166**	**116**	**64**	**83**	**57**	**180**
1,1-Dichloroethene	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
1,1,2-Trichlorotrifluoroethane	**15**	**13**	**16**	**12**	**14**	**15**	**20**	**29**	**34**	**34**
Allyl chloride	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
Methylene chloride	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
Carbon disulfide	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
trans-1,2-Dichloroethene	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Methyl tert-butyl ether	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Vinyl acetate	< 4	**5**	< 4	**6**	**10**	**5**	**11**	**8**	**4**	**5**
1,1-Dichloroethane	< 4	< 4	< 4	< 4	< 4	**5**	< 4	< 4	< 4	< 4
2-Butanone	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
n-Hexane	**4**	**6**	**8**	**10**	**12**	**11**	< 4	< 4	< 4	**6**
cis-1,2-Dichloroethene	**18**	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Ethyl acetate	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Chloroform	**6**	< 5	< 5	< 5	< 5	< 5	< 5	< 5	**5**	**20**
Tetrahydrofuran	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3	< 3
1,1,1-Trichloroethane	< 5	< 5	< 5	< 5	< 5	**6**	< 5	< 5	**5**	< 5
1,2-Dichloroethane	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Benzene	< 3	**13**	**4**	< 3	< 3	**3**	< 3	< 3	**3**	**13**
Carbon tetrachloride	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6
Cyclohexane	**4**	**4**	**3**	**5**	**5**	**4**	**19**	**9**	**4**	**6**
2,2,4-Trimethylpentane	**6**	< 5	**5**	< 5	< 5	< 5	< 5	< 5	**9**	**14**
n-Heptane	< 4	**7**	< 4	**8**	**5**	< 4	< 4	< 4	< 4	**4**
Trichloroethene	**113**	< 5	**15**	< 5	**17**	**54**	**70**	**13**	**193**	**10**
1,2-Dichloropropane	**26**	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
1,4-Dioxane	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Bromodichloromethane	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7
cis-1,3-Dichloropropene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
4-Methyl-2-pentanone	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
trans-1,3-Dichloropropene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Toluene	**94**	**9**	**31**	**5**	**83**	**41**	**10**	**10**	**14**	**23**
1,1,2-Trichloroethane	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
2-Hexanone	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Dibromochloromethane	< 9	< 9	< 9	< 9	< 9	< 9	< 9	< 9	< 9	< 9
Tetrachloroethene	**230**	**12**	**26**	**14**	**25**	**14**	**183**	**81**	**183**	**250**
1,2-Dibromoethane (EDB)	< 8	< 8	< 8	< 8	< 8	< 8	< 8	< 8	< 8	< 8
Chlorobenzene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Ethylbenzene	**56**	**10**	**13**	< 4	**5**	< 4	**5**	**5**	**5**	**21**
m,p-Xylene	**910**	**6**	**10**	**5**	**7**	**13**	**6**	**10**	**6**	**16**
Styrene	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
o-Xylene	**173**	**1127**	**34**	**1300**	**33**	**277**	**6**	**9**	**6**	**17**
Bromoform	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
1,1,2,2-Tetrachloroethane	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7	< 7
4-Ethyltoluene	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
1,3,5-Trimethylbenzene	**6**	**932**	**10**	**491**	**5**	**22**	**5**	**7**	**5**	**11**
1,2,4-Trimethylbenzene	**17**	**186**	**44**	**64**	**11**	**49**	**12**	**22**	**13**	**540**
1,3-Dichlorobenzene	< 6	< 6	**7**	< 6	< 6	< 6	< 6	< 6	< 6	< 6
Benzyl chloride	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
1,4-Dichlorobenzene	< 6	< 6	**7**	< 6	**8**	< 6	**10**	< 6	< 6	< 6
1,2-Dichlorobenzene	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6	< 6
1,2,4-Trichlorobenzene	< 7	< 7	< 7	< 7	**10**	< 7	**39**	**26**	**24**	**26**
Hexachlorbutadiene	< 11	< 11	< 11	< 11	< 11	< 11	< 11	< 11	< 11	< 11

NOTES:
1. Samples were analyzed by H&P Mobile Geochemistry, Solana Beach, California by Method TO-15.
2. Detected analytes are presented in bold type.
3. < = not detected at detection limit shown.

GROUNDWATER SERVICES, INC.

Environmental Security Technology Certification Program
(ESTCP)

RESULTS AND LESSONS LEARNED INTERIM REPORT: ALTUS AFB SITE

Attachment E

Data Evaluation Calculations

GROUNDWATER SERVICES, INC.

ATTACHMENT E: DATA EVALUATION CALCULATIONS

Altus AFB Site, Altus, Oklahoma

E.1 ATTENUATION FACTORS

Calculation E.1.1: Sub Slab to Indoor Air Attenuation Factor

$$AF_{SS-IA} = \frac{C_{IA}}{C_{SS}}$$

Where:

AF_{SS-IA}	=	Sub-slab to indoor air attenuation factor (unitless)
C_{IA}	=	Average radon concentration in indoor air (0.4 pCi//L, average from Table 11)
C_{SS}	=	Average radon concentration in sub-slab, (833 pCi//L, average from Table 11)

Example Calculation: Slab Attenuation Factor Using Radon Data

$$AF_{SS-IA} = \frac{0.4}{833}$$

$AF_{SS-IA} = 4.8 \times 10^{-4}$

GROUNDWATER SERVICES, INC.

ATTACHMENT E: DATA EVALUATION CALCULATIONS

Altus AFB Site, Altus, Oklahoma

Calculation E.1.2: Estimated Indoor Air VOC Concentrations Due to Sub-Slab Vapor Intrusion

$$C_{IA} = C_{SS} \times AF_{SS-IA}$$

Where:

C_{IA} = Estimated VOC concentration in indoor air (ug/m^3)
C_{SS} = Average VOC concentration in sub-slab, (ug/m^3, average value from Attach. F.1)
$AF_{SS\text{-}IA}$ = Sub-slab to indoor air attenuation factor for radon (4.8 x 10^{-4})

Example Calculation: Estimated indoor PCE concentration

C_{ss} = 58 ug/m^3, average of sub-slab PCE measurements, see Attach. F.1

C_{IA} = 58 ug/m^3 x 4.8 x 10^{-4}

C_{IA} = 0.028 ug/m^3

Calculation Results: Estimated VOC Concentration in Indoor Air

Compound	**Average Sub-Slab Conc. (ug/m^3)**	**Estimated Indoor Conc. (ug/m^3)**
Perchloroethene (PCE)	58	0.028
Trichloroethene (TCE)	20	0.0096

GROUNDWATER SERVICES, INC.

ATTACHMENT E: DATA EVALUATION CALCULATIONS

Altus AFB Site, Altus, Oklahoma

Calculation E.1.3 Deep Soil Gas to Indoor Air Attenuation Factor

$$AF_{SG-IA} = \frac{C_{IA}}{C_{SG}}$$

Where:

$AF_{SG\text{-}IA}$ = Deep soil gas to indoor air attenuation factor (unitless)
C_{SG} = VOC concentration in soil gas (ug/m^3)
C_{IA} = VOC concentration in Indoor Air (ug/m3, see Calc. E.1.2)

Example Calculation: Deep Soil Gas to Indoor Air Attenuation Factor For PCE

C_{SG} = 178 ug/m^3, average of highest PCE measurement (based on average from two sample events) in soil gas at each sample point cluster (450, 75, and 10 ug/m^3 for up, mid, and downgradient locations)

$$AF_{SG-IA} = \frac{0.028}{178}$$

$AF_{SG\text{-}IA}$= 1.6 x 10^{-4}

Calculation Results: Deep Soil Gas to Indoor Air AF

Compound	Average Deep SG Conc. (ug/m^3)	Deep SG to IA AF
Perchloroethene (PCE)	178	1.6 x 10^{-4}
Trichloroethene (TCE)	353	2.7 x 10^{-5}

GROUNDWATER SERVICES, INC.

ATTACHMENT E: DATA EVALUATION CALCULATIONS

Altus AFB Site, Altus, Oklahoma

Calculation E.1.4 Groundwater to Indoor Air Attenuation Factor

$$AF_{GW-IA} = \frac{C_{IA}}{C_{Gw} x H'}$$

Where:

AF_{GW-IA} = Groundwater to indoor air attenuation factor (unitless)
C_{IA} = VOC concentration in Indoor Air (ug/m3, see Calc. E.1.2)
C_{GW} = VOC concentration in Groundwater (0.039 mg/L = 39,000 ug/m3 PCE; 0.060 mg/L = 60,000 ug/m3 TCE, from upgradient well WL-436, see Fig. 7)
H' = Henry's Law constant (0.765 PCE; 0.428 TCE, http://www.tnrcc.state.tx.us/permitting/trrp.htm)

Example Calculation: Groundwater to Indoor Air Attenuation Factor for PCE

$$AF_{GW-IA} = \frac{0.028}{39{,}000 x 0.765}$$

$$AF_{GW-IA} = 9.4 \times 10^{-7}$$

Calculation Results: Groundwater to Indoor Air AF

Compound	Groundwater Conc. (ug/m^3)	GW to IA AF
Perchloroethene (PCE)	39,000	9.4×10^{-7}
Trichloroethene (TCE)	60,000	3.7×10^{-7}

GROUNDWATER SERVICES, INC.

ATTACHMENT E: DATA EVALUATION CALCULATIONS

Altus AFB Site, Altus, Oklahoma

E.2 MASS FLUX

Calculation E.2.1: Lateral Mass Flux in Shallow Groundwater Under Demonstration Building

$$F_{GW} = C_{GW} \times A \times q$$

Where

F_{GW}	=	Lateral mass flux through shallow groundwater under demonstration building (ug/day)
C_{GW}	=	Concentration of constituent in groundwater (ug/ft^3, from upgradient well WL-436, see Fig. 7)
A	=	Area through which flux is occurring (57 ft x 2 ft = 114 ft^2, width of building in direction of GW flow x 2 ft depth)
q	=	Darcy velocity = k x i = (0.076 ft/day)
k	=	Hydraulic conductivity (8.0 x 10^{-3} ft/min, average hydraulic conductivity measured at the nearest 2 wells: WL139 & WL-315, RFI report for Altus AFB)
i	=	Hydraulic gradient (0.0066, average value in vicinity of demonstration building, RFI report for Altus AFB, Figure 4.5-2, see Attachment A of this report)

Example Calculation: Mass flux of PCE in groundwater

C_{GW} = 39 ug/L (from upgradient well WL-436, see Fig. 7) = 1104 ug/ft^3

F_{GW} = 1104 ug/ft^3 x 114 ft^2 x 0.076 ft/day

F_{GW} = 9,565 ug/day

Calculation Results: Lateral mass flux in shallow groundwater

Compound	Groundwater Conc. (ug/ft^3)	GW Mass Flux (ug/day)
Perchloroethene (PCE)	1104	9,600
Trichloroethene (TCE)	1698	14,700
cis-1,2-Dichloroethene	1075	9,300

GROUNDWATER SERVICES, INC.

ATTACHMENT E: DATA EVALUATION CALCULATIONS

Altus AFB Site, Altus, Oklahoma

Calculation E.2.2: Vertical Mass Flux in Soil Column Under Demonstration Building

$$F_{SG} = D^{eff} \times \frac{\Delta C}{\Delta X} \times A$$

$$D^{eff} = D^{air} \frac{\theta_{as}^{3.33}}{\theta_T^2} + \left[\frac{D^{wat}}{H'}\right] \times \left[\frac{\theta_{ws}^{3.33}}{\theta_T^2}\right]$$

Where

F_{SG}	=	Vertical mass flux through soil column under demonstration building (ug/day)
D^{eff}	=	Effective diffusion coefficient (ft^2/day, calculated – chemical-specific)
ΔC	=	Difference in VOC concentration between deep soil gas and sub-slab (ug/m3)
ΔX	=	Depth from deep soil gas VOC concentration measurement and sub-slab (ft)
A	=	Area building foundation (8,963 ft^2, Bldg. 418)
D^{air}	=	Diffusivity in air (ft^2/day, chemical-specific)
D^{wat}	=	Diffusivity in water (ft^2/day, chemical-specific)
θ_{as}	=	Air filled porosity in soil (0.115, average from Table 1)
θ_{ws}	=	Water filled porosity in soil (0.273, average from Table 1)
θ_T	=	Total porosity in soil (0.389, average from Table 1)
H’	=	Henry’s Law constant (chemical-specific)

Effective Diffusivities

Compound	H’	D^{air} (ft^2/day)	D^{water} (ft^2/day)	D^{eff} (ft^2/day)
Perchloroethene (PCE)	0.765	6.72	8.0×10^{-4}	0.0331
Trichloroethene (TCE)	0.428	7.37	8.5×10^{-4}	0.0363
cis-1,2-Dichloroethene	0.187	6.84	1.1×10^{-3}	0.0342

GROUNDWATER SERVICES, INC.

ATTACHMENT E: DATA EVALUATION CALCULATIONS

Altus AFB Site, Altus, Oklahoma

Example Calculation: Mass Flux of PCE in soil gas (based on gradient from midgradient cluster)

D^{eff} = Effective diffusion coefficient (PCE = 0.0331 ft^2/day

ΔC = 76 ug/m^3 (average value at 4 ft bgs, midgradient) – 20 ug/m^3 (average sub-slab, midgradient) = 56 ug/m^3

ΔX = Difference between the depth of the soil gas sample and the ground surface (4ft – 0ft = 4 ft)

F_{SG} = 0.0331 ft^2/day x (56 ug/m^3 ÷ 4 ft) x 8,963 ft^2 x (1 m^3 / 35.3 ft^3)

F_{SG} = 118 ug/day

Calculation Results: Vertical mass flux in soil column

Compound	ΔC (ug/m^3)	**ΔX (ft)**	**Soil Column Mass Flux (ug/day)**
Mass flux based on concentration gradient at upgradient sample point cluster			
Perchloroethene (PCE)	315	10	265
Trichloroethene (TCE)	405	8	467
cis-1,2-Dichloroethene	71	10	62
Mass flux based on concentration gradient at midgradient sample point cluster			
Perchloroethene (PCE)	56	4	118
Trichloroethene (TCE)	6	3	18
cis-1,2-Dichloroethene	165	10	143

GROUNDWATER SERVICES, INC.

ATTACHMENT E: DATA EVALUATION CALCULATIONS

Altus AFB Site, Altus, Oklahoma

Calculation E.2.3: Mass Flux Through Demonstration Building Foundation

$$F_{SS-IA} = C_{IA} \times V \times ER$$

Where

F_{SS-IA} = Mass flux from sub-slab into building (ug/day)
C_{IA} = Steady-state concentration of constituent in indoor air (ug/m^3, from Calc. E.1.2)
V = Volume of demonstration building (89,625 ft^3 = 2,538 m^3)
ER = Building air exchange rate (16.3 day^{-1}, see Calc. E.3.1)

Example Calculation: Mass flux of PCE through building foundation

C_{IA} = 0.028 ug/m^3 (see Calc. E.1.2)

F_{SS-IA} = 0.028 ug/m^3 x 2,538 m^3 x 16.3 day^{-1}

F_{SS-IA} = 1160 ug/day

Calculation Results: Mass flux through building foundation

Compound	Indoor Air Conc. (ug/m^3)	SS to IA Mass Flux (ug/day)
Perchloroethene (PCE)	0.028	1,160
Trichloroethene (TCE)	0.0096	397
cis-1,2-Dichloroethene	<0.0024	<99

GROUNDWATER SERVICES, INC.

ATTACHMENT E: DATA EVALUATION CALCULATIONS

Altus AFB Site, Altus, Oklahoma

E.3 OTHER CALCULATIONS

Calculation E.3.1: Building Air Exchange Rate

$$\text{ER (day}^{-1}\text{)} = \frac{\text{Fresh Air Entry Rate (ft}^3\text{/day)}}{\text{Building Volume(ft}^3\text{)}}$$

$$\text{Fresh Air Entry Rate (ft}^3\text{/day)} = \frac{\text{Tracer Gas Release Rate (ft}^3\text{/day)}}{\text{Measured Tracer Gas Concentration (fraction)}}$$

Where:

ER = Building air exchange rate (day^{-1})
Fresh Air Entry Rate = Rate at which ambient air enters building (ft^3/day)
Tracer Gas Release Rate = Rate at which SF_6 tracer gas was released during test
(140 mL/min = 7.12 ft^3/day)
Measured Tracer Gas Concentration = AM: 4.22 ppmv = 4.22×10^{-6} fraction (Avg, see Table 10)
PM: 4.87 ppmv = 4.87×10^{-6} fraction (Avg, see Table 10)
Building Volume = Volume of demonstration building (89,625 ft^3)

Example Calculation: Building Air Exchange Rate, Morning sample event

$$\text{Fresh Air Entry Rate} = \frac{7.12\, ft^3/day}{4.22 \times 10^{-6}} = 1{,}687{,}000\ \text{ft}^3\text{/day}$$

ER = 1,687,000 ft^3/day / 89,625 ft^3 = 18.8 day^{-1}

Calculation Results: Building Air Exchange Rate

Measurement Time	Fresh Air Entry Rate (ft^3/day)	Air Exchange Rate (day^{-1})
Morning (7:50)	1,687,000	18.8
Evening (15:45)	1,462,000	16.3

GROUNDWATER SERVICES, INC.

ATTACHMENT E: DATA EVALUATION CALCULATIONS

Altus AFB Site, Altus, Oklahoma

Calculation E.3.2: Line Volume for Subsurface Sample Collection Methods

$$\text{LV (mL/ft)} = \frac{1}{4}\pi d^2 \text{ x } 30.48\text{cm/ft}$$

Where:

LV = Line volume per foot of line length (mL/ft)
d = Line diameter (cm)

Example Calculation: Line volume of 1/2" PVC pipe

d = 0.625" (Inside diameter) = 1.6 cm
LV = 0.25 x 3.14 x (1.59 cm)^2 x 30.48 cm/ft
LV = 60 mL/ft

Calculation Results: Line Volume for Subsurface Sample Collection Methods

Sample Line	Line Diameter (cm)	Line Volume (mL/ft)
1/2 Inch PVC (ID = 0.625")	1.59	60
1/4 Inch Tubing (ID = 0.25")	0.635	9.6
1/8th Inch Nylaflow (ID = 0.078")	0.198	0.94

GROUNDWATER SERVICES, INC.

Environmental Security Technology Certification Program
(ESTCP)

RESULTS AND LESSONS LEARNED INTERIM REPORT: ALTUS AFB SITE

Attachment F

Statistical Analyses

GROUNDWATER SERVICES, INC.

ATTACHMENT F.1
STATISTICAL ANALYSIS: SPATIAL VARIABILITY OF PCE AND TCE RESULTS
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

Tetrachloroethene		Average Sample Result			Summary Statistics		
		Upgradient	Midgradient	Downgradient	Average	Standard Deviation	Coefficient Of Variation
Environmental Medium	***Units***						
Ambient	ug/m3	< 5	< 5	< 5	5	0	0
Indoor	ug/m3	6	< 5	< 5	5	1	0.108
Sub slab	ug/m3	135	20	21	58	66	1.135
1 ft Soil Gas	ug/m3	6	23	8	12	9	0.753
2 ft Soil Gas	ug/m3	nm	26	9	18	-	-
3 ft Soil Gas	ug/m3	< 5	52	7	21	27	1.246
4 ft Soil Gas	ug/m3	< 5	76	8	30	40	1.354
3.5-4.5 ft Well Headspace	ug/m3	10	nm	10	10	-	-
5.5-6.5 ft Well Headspace	ug/m3	28	nm	6	17	-	-
7.5-8.5 ft Well Headspace	ug/m3	130	20	5	52	68	1.321
9.5-10.5 ft Well Headspace	ug/m3	450	< 5	< 5	153	257	1.676
3.5-4.5 ft Groundwater	mg/L	nm	nm	nm	-	-	-
5.5-6.5 ft Groundwater	mg/L	< 0.00023	nm	< 0.00023	0.00023	-	-
7.5-8.5 ft Groundwater	mg/L	nm	nm	0.0032	-	-	-
9.5-10.5 ft Groundwater	mg/L	nm	< 0.00023	0.00245	0.00134	-	-

Trichloroethene		Average Sample Result			Summary Statistics		
		Upgradient	Midgradient	Downgradient	Average	Standard Deviation	Coefficient Of Variation
Environmental Medium	***Units***						
Ambient	ug/m3	< 5	< 5	< 5	5	0	0
Indoor	ug/m3	< 5	< 5	< 5	5	0	0
Sub slab	ug/m3	44	7	10	20	21	1.017
1 ft Soil Gas	ug/m3	< 5	5	< 5	5	0	0
2 ft Soil Gas	ug/m3	nm	< 5	< 5	5	-	-
3 ft Soil Gas	ug/m3	< 5	14	< 5	8	5	1
4 ft Soil Gas	ug/m3	< 5	7	< 5	6	1	0
3.5-4.5 ft Well Headspace	ug/m3	8	nm	< 5	6.5	-	-
5.5-6.5 ft Well Headspace	ug/m3	125	nm	50	88	-	-
7.5-8.5 ft Well Headspace	ug/m3	450	130	380	320	168	0.526
9.5-10.5 ft Well Headspace	ug/m3	390	11	480	294	249	0.848
3.5-4.5 ft Groundwater	mg/L	nm	nm	nm	-	-	-
5.5-6.5 ft Groundwater	mg/L	0.0022	nm	0.0019	0.0021	-	-
7.5-8.5 ft Groundwater	mg/L	nm	nm	0.14	0.14	-	-
9.5-10.5 ft Groundwater	mg/L	nm	< 0.0001	0.11	0.055	-	-

GROUNDWATER SERVICES, INC.

ATTACHMENT F.2
STATISTICAL ANALYSIS: TEMPORAL VARIABILITY OF GROUNDWATER RESULTS
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

	Perchloroethene			
	Sampling Event 1	Sampling Event 2	Difference	Relative Percent Difference
Sample Location	mg/L	mg/L	mg/L	%
MW-9	< 0.00023	< 0.00023	0	0%
MW-7	0.0032	0.0032	0	0%
MW-5	0.0019	0.003	0.0011	45%

	Trichloroethene			
	Sampling Event 1	Sampling Event 2	Difference	Relative Percent Difference
Sample Location	mg/L	mg/L	mg/L	%
MW-9	< 0.0001	< 0.0001	0	0%
MW-7	0.14	0.15	0.01	7%
MW-5	0.1	0.11	0.01	10%

	cis 1,2-Dichloroethene			
	Sampling Event 1	Sampling Event 2	Difference	Relative Percent Difference
Sample Location	mg/L	mg/L	mg/L	%
MW-9	0.0073	0.0064	0.0009	13%
MW-7	0.17	0.14	0.03	19%
MW-5	0.012	0.012	0	0%

NOTE:
1) Table shows analytical results for all sample points sampled during both sample event 1 and sample event 2.

GROUNDWATER SERVICES, INC.

ATTACHMENT F.3
STATISTICAL ANALYSIS: TEMPORAL VARIABILITY OF WELL HEADSPACE RESULTS
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

	Perchloroethene			
	First Sampling Event	Second Sampling Event	Difference	Relative Percent Difference
Sample Location	ug/m3	ug/m3	ug/m3	%
MW-3	12	40	28	108%
MW-6	5	7	2	33%
MW-9	5	5	0	0%

	Trichloroethene			
	First Sampling Event	Second Sampling Event	Difference	Relative Percent Difference
Sample Location	ug/m3	ug/m3	ug/m3	%
MW-3	56	180	124	105%
MW-6	57	43	14	28%
MW-9	15	7	8	73%

	cis 1,2-Dichloroethene			
	First Sampling Event	Second Sampling Event	Difference	Relative Percent Difference
Sample Location	ug/m3	ug/m3	ug/m3	%
MW-3	5	5	0	0%
MW-6	5	5	0	0%
MW-9	270	100	170	92%

NOTE:

1) Table shows analytical results for all sample points sampled during both sample event 1 and sample event 2.

GROUNDWATER SERVICES, INC.

ATTACHMENT F.4
STATISTICAL ANALYSIS: TEMPORAL VARIABILITY OF SOIL GAS RESULTS
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

	Perchloroethene			
	First Sampling Event	Second Sampling Event	Difference	Relative Percent Difference
Sample Location	ug/m3	ug/m3	ug/m3	%
SG-3	< 5	< 5	0	0%
SG-4	< 5	< 5	0	0%
SG-5	16	7	9	78%
SG-6	13	7	6	60%
SG-7	10	< 5	5	67%
SG-8	9	7	2	25%
SG-9	23	22	1	4%
SG-10	27	24	3	12%
SG-11	54	49	5	10%
SG-12	95	56	39	52%

	Trichloroethene			
	First Sampling Event	Second Sampling Event	Difference	Relative Percent Difference
Sample Location	ug/m3	ug/m3	ug/m3	%
SG-3	< 5	< 5	0	0%
SG-4	< 5	< 5	0	0%
SG-5	< 5	< 5	0	0%
SG-6	< 5	< 5	0	0%
SG-7	< 5	< 5	0	0%
SG-8	< 5	< 5	0	0%
SG-9	5	< 5	0	0%
SG-10	< 5	< 5	0	0%
SG-11	14	13	1	7%
SG-12	6	8	2	29%

NOTE:
1) Table shows analytical results for all sample points sampled during both sample event 1 and sample event 2.

GROUNDWATER SERVICES, INC.

ATTACHMENT F.5
STATISTICAL ANALYSIS: TEMPORAL VARIABILITY OF SUBSLAB RESULTS
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

	Perchloroethene			
	First Sampling Event	Second Sampling Event	Difference	Relative Percent Difference
Sample Location	ug/m3	ug/m3	ug/m3	%
SS-1	130	140	10	7%
SS-2	16	18	2	12%
SS-3	22	18	4	20%

	Trichloroethene			
	First Sampling Event	Second Sampling Event	Difference	Relative Percent Difference
Sample Location	ug/m3	ug/m3	ug/m3	%
SS-1	39	49	10	23%
SS-2	8	9	1	12%
SS-3	8	7	1	13%

NOTE:
1) Table shows analytical results for all sample points sampled during both sample event 1 and sample event 2.

GROUNDWATER SERVICES, INC.

ATTACHMENT F.6
STATISTICAL ANALYSIS: TEMPORAL VARIABILITY OF INDOOR AND AMBIENT RESULTS
ESTCP: Vapor Intrusion Study
Altus Air Force Base, Altus, Oklahoma

	Perchloroethene			
	First Sampling Event	Second Sampling Event	Difference	Relative Percent Difference
Sample Location	ug/m3	ug/m3	ug/m3	%
Ambient 1	< 5	< 5	0	0%
Ambient 2	< 5	< 5	0	0%
Ambient 3	< 5	< 5	0	0%
Indoor 1	< 5	7	2	33%
Indoor 2	< 5	< 5	0	0%
Indoor 3	< 5	< 5	0	0%

	Trichloroethene			
	First Sampling Event	Second Sampling Event	Difference	Relative Percent Difference
Sample Location	ug/m3	ug/m3	ug/m3	%
Ambient 1	< 5	< 5	0	0%
Ambient 2	< 5	< 5	0	0%
Ambient 3	< 5	< 5	0	0%
Indoor 1	< 5	< 5	0	0%
Indoor 2	< 5	< 5	0	0%
Indoor 3	< 5	< 5	0	0%

NOTE:
1) Table shows analytical results for all sample points sampled during both sample event 1 and sample event 2.

GROUNDWATER SERVICES, INC.

Environmental Security Technology Certification Program
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RESULTS AND LESSONS LEARNED INTERIM REPORT: ALTUS AFB SITE

Attachment G

Response to Comments

GROUNDWATER SERVICES, INC.

RESPONSE TO COMMENTS:
RESULTS AND LESSONS LEARNED INTERIM REPORT FOR ALTUS AFB SITE

ESTCP Project No. CU-0423

Specific Comments on the Results and Lessons Learned Interim Report: Altus AFB ESTCP Project No. CU-0423

1. The single most significant result and concern for the study is that PCE and TCE were not detected in the indoor air samples (Table 7), yet significant concentrations were measured in the sub-slab soil gas (16-140 _g/m^3) (Table 6). The attenuation factor's (page 32) estimates of mass flux to indoor air (page 29), and assessment of false-positives associated with the EPA's default attenuation factors are based solely on the measured attenuation of radon (page 34). The study results would be stronger if the detection limits for PCE and TCE in indoor air were closer to the EPA screening values considered protective of human health (10^{-6} risk level, 0.81 and 0.022 _g/m^3 for PCE and TCE, respectively) (Section 4.4.1). The typical detection limits for low level TO15 analysis are in the range of 1.2 and 0.9 _g/m^3 for PCE and TCE, respectively, when 6-L Summa canisters are used. Is it possible to confirm with actual indoor air quality data that the indoor air is below the 10^{-6} or at least the 10^{-5} risk level for PCE and TCE? Is there an indoor air method for PCE and TCE that could be used to confirm the attenuation factor estimated by the measurement of radon? Please discuss.

Response: Although we achieved detection limits equal to the standard reporting limits for TO-15, we agree that lower detection limits would be informative and recognize that many laboratories offer lower detection limits for TO-15. For all future sampling at Altus and the other test sites, we plan to use 6-L Summas and a laboratory that can achieve lower detection limits for all indoor air samples and at least one ambient air sample. We anticipate detection limits in the range of 1 ug/m^3 or better for these samples.

Revision: A new Section 5.3 has been added to Section 5 (Lessons Learned) to discuss the modified plan for collection and analysis of indoor air samples.

2. The building air pressure was on average slightly positive compared to the sub-slab air pressure during the testing program; however, significant positive and negative excursions in indoor air pressure occurred during the day when the building was occupied (page 22). Could the indoor air pressure be slightly negative on average under different conditions (e.g. greater heating load)? What might happen to the indoor air quality if the air exchange rate in the building is reduced from 16-19/day to a lower value in an effort to conserve energy? How does the current air exchange rate compare to ASHRAE standards?

Response: The HVAC system was reported to circulate air at a rate of 7,615 CFM with a minimum of 15% outdoor air. The fresh air intake rate increases during cool weather in order to decrease the building cooling load, however, the intake does not fall below 15% during either hot or cold weather. Based on the building size of 89,600 ft^3, the expected minimum building air exchange rate is 18/day. If air exchange rates were to fall below the measured 16-19/day values due to improper or unexpected operation of the HVAC system, indoor air quality could decrease. All else being equal, a decrease of 50% in building ventilation rates would double the indoor air concentration of any chemicals entering the building through vapor intrusion.

GROUNDWATER SERVICES, INC.

RESPONSE TO COMMENTS:
RESULTS AND LESSONS LEARNED INTERIM REPORT FOR ALTUS AFB SITE

ESTCP Project No. CU-0423

ASHRAE Standard 62.1-2004 provides different recommendations for commercial building ventilation rates based on building use. The recommended ventilation rates range from a low of 12/day for office space to >100/day for high occupancy spaces likely to experience poor indoor air quality, such as bars and restaurants. The demonstration building is used for classroom instruction (recommended ventilation rate: 65/day), however, the building occupancy appeared to be significantly lower than a typical building used for classroom instruction. As a result, the measured building ventilation rate is likely appropriate for the current building use.

Revision: None

3. Given the above comments, the finding presented on page 28 that "An evaluation of both measured and estimated indoor air VOC concentrations indicated that vapor intrusion impact has not occurred for building 418.", maybe too strong of a statement. Please consider rewording this statement to account for study limitations.

Response: We agree that the conclusions regarding vapor intrusion impacts should be limited to the timeframe of the sampling event.

Revision: The text on page 28 has been expanded to include a discussion of factors that could influence temporal variability in vapor intrusion.

4. The [a-pinene] detected in soil gas could be from spills of cleaning solutions (page 16). This volatile compound is commonly found in indoor air from cleaning products. Was this compound detected in groundwater? Was it detected in lab blanks or other non-soil gas samples on the same day? Please discuss.

Response: Based on the analytical program completed for the Altus demonstration, we had the ability to detect a-pinene only in soil gas samples collected at the downgradient monitoring cluster (i.e., the cluster completed within the pine trees). As a result, we were unable to confirm the presence or absence of a-pinene at other location or within other media (i.e., groundwater). We were able to detect the presence of a-pinene in soil gas samples collected from the downgradient monitoring cluster because these samples were analyzed at the on-site mobile lab by Method 8260B. The on-site analyst noted the vary large unexpected peak on the GC and was able to identify the compound as a-pinene based on the mass spectrum. Because a-pinene is not on the standard analyte list for 8260B or TO-15, it is unlikely that the presence of a-pinene in these samples would have been reported by an off-site lab. We were not able to determine the presence or absence of a-pinene in other gas samples, because all other gas samples were analyzed by 8260B-SIM, allowing for the quantification of only a short list of selected analytes. The presence or absence of a-pinene was not reported in groundwater samples analyzed off-site because a-pinene is not on the standard 8260B analyte list. a-Pinene was not detected in lab blanks run by the on-site mobile lab.

Although we were not able to quantify the presence or absence of a-pinene at other locations, an evaluation of total VOC concentrations by PID indicated that the downgradient monitoring cluster (i.e., the location where a-pinene was detected) was the only location with very high total VOC concentrations.

GROUNDWATER SERVICES, INC.

RESPONSE TO COMMENTS:
RESULTS AND LESSONS LEARNED INTERIM REPORT FOR ALTUS AFB SITE

ESTCP Project No. CU-0423

Total VOC concentrations at the downgradient cluster were >1000 ppm, while maximum total VOC concentrations at all other subsurface sample point locations were <100 ppm. In addition, a building survey conducted using a ppb-level PID showed no detectable VOCs at any location in the building at a detection limit of approximately 0.010 ppm. Although the a-pinene detected at the downgradient monitoring cluster could have originated from discarded cleaning product, the pine trees seem to be the most likely source based on their proximity to the sample points. However, a definitive determination of the source of the a-pinene is not required for evaluation of the Altus results.

Revision: None

5. It’s not surprising that the mini Summa canisters were not clean enough to meet the data quality objectives for the low level indoor air analysis (page 36). The mini canisters are often used for soil gas samples and other air samples that have high concentrations of VOCs because lower detection limits are achieved by the smaller sample size. Please use 6-L Summa canisters and have each one certified as clean for this study.

Response: Based on the problems we experienced, H&P (i.e., the lab supplying the mini-Summas) has revised it’s canister cleaning program. However, as discussed above, 6L Summas will be used for all future indoor air samples in order to achieve lower detection limits. In addition, all mini-Summas supplied by H&P for this project will be individually tested clean prior to use for collection of subsurface gas samples.

Revision: A new Section 5.3 has been added to Section 5 (Lessons Learned) to discuss the modified plan for collection and analysis of indoor air samples.

6. Some comparisons should be made at this point to the current published peer-reviewed literature (Section 5). How do these results compare to the peer-reviewed literature? Are these results new or different than what is being published? Can data be collected during the remainder of the testing program to provide conclusions that are important enough for publication in a peer-reviewed technical paper? How will the technology transfer plan unfold?

Response: The primary focus of this interim report has been to evaluate the quality and utility of the data collected from the Altus demonstration. The purpose of this focus has been to identify any modifications required to improve the quality of the results obtained for the subsequent demonstrations while maintaining as much consistency as possible in data collection methods between the sites in order to ensure that the results obtained from the three demonstration sites are comparable.

Because the focus on vapor intrusion as an important exposure pathway is relatively recent, little peer-reviewed literature is available on the subject. We are not aware of any study site that has been characterized with as many samples collected in close proximity to a single building. For most sites presented in the literature, only a small fraction of this data is available. As a result, the ability to compare the results from Altus to peer-reviewed literature is somewhat limited. However, we have included a comparison to results obtained from other sites in our interim report, when possible (e.g., analysis of the radon results).

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Following completion of data collection from all three demonstration sites, we anticipate that the results will be presented in one or more peer-reviewed publications. Potential topics for peer-reviewed papers include: i) use of radon analyses for evaluation of vapor intrusion, ii) use of mass-flux analyses for evaluation of vapor intrusion, iii) spatial and temporal variability on VOC distribution along the vapor intrusion pathway, and iv) validation of a cost-effective and reliable limited field investigation of vapor intrusion.

Plans for technology transfer are included in the original project proposal and the Altus demonstration plan and include:

Vapor Intrusion Fact Sheet: A fact sheet will be developed to communicate the project results to regulators and other interested parties. The fact sheet will summarize how the project has increased our understanding of the potential for vapor intrusion at corrective action sites and will provide suggestions for pathway screening based on site characteristics and for focused field investigations at sites where pathway screening does not eliminate the pathway.

Pathway Screening Worksheet: Based on the differences in vapor intrusion processes observed at the different test sites, a pathway screening worksheet will be developed. This worksheet will identify sites with low potential for vapor intrusion impacts based on the evaluation of site parameters typically characterized during the site investigation (e.g., soil type, depth to groundwater, and constituent type).

Web Accessible Reference Data Set: The project results will be compiled into a reference data set that can be utilized by other environmental professionals for the evaluation of vapor intrusion processes. This comprehensive and well-documented data set could be used for model development and validation or comparison of vapor intrusion processes at other research sites.

Conference Presentations and Peer-Reviewed Papers: The results of the project will be presented at relevant scientific conferences and submitted to peer-reviewed journals for publication.

Revision: None.

7. There may be opportunities to develop selected tools and guidance from this study. Please consider and discuss the possibility of the following items:
    a. The tracer gas study (p. 26) used to calculate air exchange rates from the demonstration building may represent a tool to optimize future HVAC operations.
    b. Your evaluation that the default USEPA attenuation factors significantly over-estimate the potential for vapor intrusion (p. 32) could be a basis to provide a more realistic attenuation consideration to the user community.
    c. The sub-slab VOC concentration data combined with sub-slab and indoor radon data providing an accurate evaluation of vapor intrusion impact (p. 34) may represent future protocols for assessing the vapor intrusion process.

Response: We agree that topics b and c will be important focus areas following evaluation of all three demonstration sites. Although the results from the Altus site are encouraging, evaluation of the additional

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sites is needed in order to understand whether these methods and results are widely applicable at vapor intrusion sites. As discussed in item 6, above, we are planning on using a variety of technology transfer methods to communicate the results of our project. We anticipate that the results will support the consideration of alternative screening procedures for vapor intrusion sites (topic b) and will provide validation of alternative vapor intrusion field investigation methods (topic c).

The use of tracer gas to evaluate and optimize HVAC system operation (topic a) is addressed in ASTM Standard E-741-00 and other publications. It is not clear that the results from this study will contribute significantly to this area. However, operation of the HVAC system to maintain positive building pressures and the use of pressure gradient measurement to verify these positive pressure conditions may prove to be an effective tool for limiting vapor intrusion impacts to buildings.

Revision: None.